THE ROMANCE OF MODERN ELECTRICITY

By CHARLES R. GIBSON

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PASSENGER HOIST ON THE WETTERHORN

One car is ascending while the other is descending. The cars are drawn by a cable passing through the upper station, which is seen in the top left-hand corner of the photograph. This house contains an electric motor which drives the cable, while the electric current is supplied very conveniently from a lower station. A photograph of the upper station is shown facing page 20.

THE ROMANCE OF MODERN ELECTRICITY

DESCRIBING IN NON-TECHNICAL LANGUAGE WHAT IS KNOWN ABOUT ELECTRICITY AND MANY OF ITS INTERESTING APPLICATIONS

BY

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"THE ROMANCE OF MODERN PHOTOGRAPHY"
"SCIENTIFIC IDEAS OF TO-DAY," ETC.

NEW & REVISED EDITION

WITH THIRTY-FOUR ILLUSTRATIONS
& THIRTEEN DIAGRAMS

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PREFACE

TO THE REVISED EDITION

THE first edition of this work was published towards the end of 1905, and while repeated editions have been called for, these have been merely reprints. But things move quickly in the electrical world, and since the first edition was published much has happened in several departments. Wireless telegraphy has made great strides, and wireless telephony has passed from the experimental stage into the business world. A good deal of new matter has been added in connection with these; an entirely new chapter having been added on wireless telephony. Owing to very interesting advances in the working of telephone exchanges, the greater part of Chapter XIV is new. Then our ideas concerning the inner nature of electrical phenomena have been extended very considerably by the advent of the electron theory; a good deal of new matter has been added in this connection. In addition to these matters the whole text has been carefully revised so that it covers any new ground.

The author is indebted again to Professor Magnus Maclean, MA., D.SC., F.R.S.E., for very kindly reading the proof-sheets. Also to William Allan, A.M.I.E.E. (Chief Electrician to the National Telephone Company in Glasgow) for reading the chapters dealing with telephony. And to J. Erskine-Murray, D.SC., F.R.S.E., M.I.E.E. (Consulting Wireless Telegraphist) for reading those chapters relating to communication through space.

PREFACE

TO THE FIRST EDITION

THE younger members of the present generation have become so accustomed to the practical applications of electricity that it is very difficult for them to appreciate the marvellous difference that the advent of electricity has made in everyday life.

If the present conditions of life had been correctly predicted a few generations ago, the prophet would have received little attention, or would have been made a laughing-stock. It certainly would have seemed quite incredible that people would some day be able to send messages, with lightning speed, across the seas to the very ends of the earth, and learn in return what was actually taking place there at the very moment, instead of waiting many weary weeks for news to be carried by road or sea. It would have seemed even more impossible that people would ever be able to carry on actual conversation with friends distant many hundreds of miles from them.

While the simple phenomena of the lodestone and the rubbed amber were known to the people of many centuries ago, little did they dream then that these feeble properties would soon be increased to a gigantic power, which would propel great heavy vehicles across the country, each carrying many hundreds of passengers. No one would have thought that electricity would serve to light up the darkness of great cities.

PREFACE

If one had foretold that all this immense power required for propulsion, or for lighting, would be transmitted along a solid and stationary wire stretched between two distant places, there would have been many people willing to declare that such a thing was against all the laws of nature.

It is very doubtful if the most optimistic philosopher of a century ago would have believed that this so-called electricity would enable the physicians of the future not only to see and photograph each bone and joint in the living skeletons of their patients, but also to see and watch the movements of the heart and other organs of the human body.

The present generation, having grown up amidst all these and other wonders, has almost ceased to marvel at them. If the ordinary man of business stops to think of them, how often does he pass them over as things not easily understood, and rest content to take things as he finds them without questioning the why and wherefore. However difficult it may be to discover what electricity really is, there is no reason why both young and old should not understand how it is harnessed and made to do useful work.

The hurly-burly of present-day life is so great that few have the time, or the inclination, to study the subject in scientific text-books, but the author hopes to show in the present volume that some clear understanding of the subject may be obtained in a simple and pleasant manner.

AUTHOR'S NOTE

The author is indebted to Professor Magnus Maclean, M.A., D.SC., F.R.S.E. (Professor of Electrical Engineering in the Glasgow and West of Scotland Technical College), for very kindly reading the proofs, and to Dr. Lee de Forest and the National Electrical Signalling Co., U.S.A., for particulars regarding their respective systems of wireless telegraphy.

In connection with the illustrations the author is indebted to the following firms, journals, and individuals: Siemens and Halse, Siemens Schuckert Werke, Berlin; Wilhelm Fülle, Barmen; The Automatic Electric Co., Chicago; *The Scientific American*, New York; The National Electric Signalling Co., U.S.A.; The Electrical Co., Ltd.; *The Electrical Magazine;* Merryweather and Sons, Ltd.; The India Rubber and Telegraph Works Co., Ltd., London; The National Telephone Co., Ltd.; The Glasgow Corporation Telephone Department; Mavor and Coulson, Ltd.; Giesserei Bern, Switzerland; Richard Kerr, F.G.S., F.R.A.S.; John M. B. Taylor; John Whiteside; Alex. McGrouther; and Mr. Stacey, Dunmow.

CONTENTS

CONTENTS

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF DIAGRAMS

THE ROMANCE OF MODERN ELECTRICITY

CHAPTER I

THE PART PLAYED BY ELECTRICITY

A seeming lack of interest which is not real—The character of electricity—Mystery concerning the nature of electricity—Lightning—Some of electricity's manifold duties.

MANY people believe honestly that a knowledge of electrical matters is beyond their reach. Some years ago I got into conversation with the postmaster in a little country village. Finding that he had no conception whatever of the way in which his telegraph instrument worked, I explained it to him in a few words. It was amusing to see his surprise; he had supposed that to know such things required a "second edication."

It has always been a matter of wonderment to me how so many people are content to pass through life taking advantage of all the modern applications of electricity and yet apparently indifferent to the means by which those modern marvels are worked. As indicated in the opening sentence, however, much of this seeming lack of interest has been due to a misapprehension. And from

the enthusiastic reception accorded to the earlier editions of this present "Romance," it is quite evident that the general reader is genuinely interested in the subject of electricity.

There is no gainsaying the fact that much relating to the nature of electricity is shrouded in mystery, but that does not mean that there is any mystery concerning the working of telegraphs, telephones, electric motors, dynamos, and all the other practical applications of electricity.

By pointing to the falling weights in a grandfather clock, it is not difficult to let a child understand how the wheels go round. But the most learned scientist has no definite idea of the *nature* of the force which causes the weights to fall. It is not recognised by many that our ideas concerning the nature of *electricity* are much more definite than those regarding *gravitation*. However, it is evident that we can proceed to consider how electricity is applied without waiting to discuss the present ideas concerning its nature. After we have become familiar with electricity at work, it will be of interest to see how far we have unravelled the mystery of its nature.

No doubt many readers have some sort of nodding acquaintance with electrical appliances. In any case, we are all familiar with the telephone, and we have, no doubt, seen some form of electric telegraph instrument. Those who have made no study of such instruments have doubtless surrounded them with an atmosphere of mystery. To any one who cares to consider the matter seriously it must be clear that all such instruments are made of pieces of ordinary metal, wood, glass, and such like. There is no mystery about the apparatus. The dynamos

which are supplying the electric current for lighting a whole city are merely collections of pieces of iron and brass, and bundles of wires.

Perhaps our earliest recollections of electricity are in connection with Nature's grand display. We have childhood memories of those huge electric sparks which we call *lightning*. These great electrical demonstrations have been known to men of the remotest ages; indeed, we are safe in saying that there were lightnings and thunders before man was created. We shall see later that the ancients failed to recognise the nature and origin of the lightning. But what I wish to point out at present is the fact that electricity is as old as the world itself. Sometimes one hears people speak of electricity as though it were an invention of modern man. It is true that only in modern times has electricity been harnessed and made to do useful work, but all the electricity which we can call to our service to-day has been in existence, in some available form, from the beginning of this world.

It is of interest to notice the nature of the part played by electricity. Electricity is in reality a go-between. For instance, if we pay a visit to the power-house which supplies electricity for driving the tramway cars in a great city, we see much evidence of energy. There is the immense heat energy of the great furnaces, producing the necessary steam pressure to drive huge engines. In the going parts of the great engines we get some idea of the vast amount of energy which is being used. We see these engines driving large dynamos, but after this we lose sight of all evidence of the energy. It has been handed on to the care of the invisible go-between, which we call electricity.

The invisible electric current is now the means of carrying the energy out to the distant tramway cars. There it enters the electric motors which are beneath the cars and causes the wheels to turn round. As we watch the tramway car, with fifty people on its back, climb a steep hill, we see once more that the energy which left the great power-house has not been lost. We shall understand later how the dynamos and motors work; for the present we wish to realise that electricity is a most helpful go-between.

Our object in the present volume is to see how electricity has been harnessed to assist us in our every-day life. We have noted already its application in transmitting energy to a distance. We shall see also the means by which it produces that most convenient of all forms of artificial light.

It will be of interest also to see how electricity has enabled man, by means of the electric telegraph, to communicate with his fellow-men in every civilised part of this great planet. Then again it seems almost incredible that we can telegraph to ships far out on the ocean, even when we do not know their exact whereabouts. Yet we shall see that the methods of doing so are easily understood.

Perhaps we have ceased to marvel at the fact that a man in London can carry on ordinary conversation with a friend in Paris, or in the distant capital of Scotland. When we come to consider the means by which this is accomplished we cannot fail to be interested.

The fact that we can now speak over a great distance through space, without the aid of any connecting wires,

is one of the latest practical achievements in the electrical world.

Electricity has proved a most helpful handmaiden to Chemistry in the industrial world. In addition to the practical side of the subject, we shall see that all chemical actions are in reality due to electrical activities between the particles of which all substances are composed.

In many other directions we shall find electricity coming to man's aid. To mention only one other practical application, we might select the means of producing Röntgen rays, which have proved of the greatest possible assistance to the physician. We shall have no difficulty in seeing how electricity works all these modern marvels.

While the title of this volume is "The Romance of *Modern* Electricity," it will be of interest to see what little the ancients did know of this great agent. Although this takes our story back several thousand years, we shall see that all the practical applications of electricity are very modern. Indeed, most of the advances which electricity has made into our everyday life have taken place within the personal recollection of very many of us.

Those of us who can compare the condition of electrical undertakings of to-day with those which existed twenty-five years ago, are forced to wonder what further advances may be made during the next twenty-five years. However, it will be of interest to us to commence the story at the beginning, and consider how we came to know about electricity.

CHAPTER II

HOW WE CAME TO KNOW ABOUT ELECTRICITY

Early magic in the East—The Chinese discover a peculiar stone which guides them across the deserts—Peculiar property possessed by amber—One of Queen Elizabeth's physicians makes important discoveries—The earliest electrical machines—A modern giant machine—The present use of such apparatus.

THOUSANDS of generations of men spent their lives upon this planet without acquiring any knowledge of this wonderful agent which we call *electricity.* King Solomon declared that there is nothing new under the sun; electricity is not a new thing. All the electricity, all the matter, and all the energy which exist to-day have existed from the beginning of the world.

Of course it may be that the ancient wise men of the East knew much more of this subject than we give them credit for. It is very probable that electric and magnetic phenomena formed the basis of much of the magic of these early times; and some writers have even suggested that Tullus Hostilius, instead of being "struck down dead by a thunderbolt from Jove for practising magical arts," was more prosaically robbed of life by being the recipient of a fatal electric shock. This would certainly have been possible had Tullus Hostilius been experimenting after the fashion of Franklin and others in a thunder-

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THE UPPER STATION ON THE WETTERHORN

To realize the height at which this station is, one must refer to the frontispiece. When the cars are nearing a stopping-place they automatically switch off the electric current, and should any accident occur to the car or the cable a magnetic brake comes into action and stops the car immediately.

storm. Be that as it may, we should be able to find sufficient interest among the actual facts recorded.

To trace how man came to know about electricity one has to go back to a date at least one thousand years before Christ. It is recorded that at this early date the Chinese were in possession of a certain kind of stone which, when supported in the outstretched arm of a little revolving figure on their caravans, guided them across the trackless wastes of Tartary. Exactly how and when they discovered the peculiar property of this stone is not known, but we must reckon this discovery as a definite starting-point in our knowledge of electricity. Some authorities claim that this stone, which was christened lodestone (leading-stone), was known as early as 2600 B.C. It is a class of iron ore, presumably magnetised by the earth's influence, and is found in many parts of the world.

No doubt the ancients would first observe that this lodestone attracted small pieces of iron, and that these held on to it with a tenacity that might have suggested the presence of life, which phenomenon would doubtless be quite satisfactorily explained in those days by admitting that the stone had a soul.

This stone would be a wonder to the wise men, and many would gain possession of a specimen, so that it would not be long before someone observed that when a piece of this material was freely suspended, it always came to rest in a certain definite position, which from observation turned out to be with one end pointing north and the other end pointing south.

It was a further step in advance when it was found that this lodestone was able to impart its own peculiar

properties to a piece of iron in contact with it, and that when the stone was repeatedly drawn along a piece of hard iron the latter came to possess these properties in some degree on its own account, and without any loss of power to the lodestone. Such pieces of iron were called magnets, this word probably being derived from Magnesia, a place in Asia Minor, where the lodestone was obtained in some quantity.

Another phenomenon was observed in those early days, which is recorded by a Greek philosopher as far back as 600 B.C., but which until modern times was not supposed to have any connection with the lodestone phenomena. It was found that when a piece of amber (a mineralised resin of extinct pine trees) was rubbed, it would attract any light bodies towards itself, as for instance, pieces of straw, paper, etc. The schoolboy may repeat this old-world experiment by simply rubbing a piece of sealing-wax upon his coat-sleeve. Of course, it is evident that this attractive property is not the same as that of the lodestone, which will attract only iron, while the rubbed amber is able to attract any light body. However, we shall not have gone far before we see the very intimate connection which exists between these two apparently different phenomena.

Man's further knowledge of these phenomena seems to have made no progress until one of Queen Elizabeth's physicians made a special study of the properties of lodestone and rubbed amber, and he got so far ahead of the knowledge of his time (1600 A.D.) that practically nothing of importance was added till the close of the eighteenth century.

This great genius, Dr. Gilbert, of Colchester, discovered that the old-world phenomenon of attraction did not belong only to amber, but that a great number of things acted in the same way when rubbed. More than a century passed before it was found that all bodies, if certain conditions were observed, would exhibit this property of attraction. By briskly rubbing a piece of well-dried brown-paper with an ordinary clothes-brush, I have succeeded in getting the paper to exhibit electrical attraction. Of course some bodies act very much better than others, and so it has been found by experiment that a piece of vulcanite rubbed with a cat's skin, or a glass rod "excited" by a piece of silk cloth, give the best results obtainable by simply rubbing them together.

Our word "electricity" is a fitting memorial of the ancient amber experiment, as it is derived from the Greek word ἤλεκτρον (electron) signifying amber.

After Dr. Gilbert's discovery became known, people set about making machines to do the rubbing for them on a larger scale. The earliest of these machines consisted merely of a large sulphur ball rotated on a spindle, while the experimenter used his hand as the rubber by holding it against the revolving ball. Glass cylinders soon replaced the sulphur ball, and even with such primitive apparatus an electric spark was produced. It was also found that if two bodies were similarly electrified by touching the excited glass cylinder, these two bodies when brought near to each other repelled one another, while each continued to attract any other light body.

Working with this same simple apparatus, in the early part of the eighteenth century, it was found that this

electrical influence could be transmitted along a number of pack threads (suspended by silk threads) to a distance of about 300 yards; and a few years later it was observed that when the pack threads were wetted the distance might be increased to over 400 yards.

It was only natural that improvements should be added to these early machines from time to time, and the first step in this direction was the introduction of a leather cushion, to act as the rubber in place of the experimenter's hand. Then suitable means were devised for collecting the electrical influence from the machine. In modern "influence" or "statical" machines there is no actual rubbing. Two glass or vulcanite plates, each carrying a series of small slips of thin metal foil upon them, are made to revolve close to each other in opposite directions, and by a process known as "induction," an electrical charge is induced on the plates and suitably collected. If a number of pairs of plates are used a very big electrical effect may be produced. The late Lord Blythswood constructed in his private laboratory an immense electrical machine, having 160 plates, each measuring three feet in diameter, and it would be no pleasure for a person of nervous temperament to be in the immediate neighbourhood of this machine while it discharges lightning flashes with an almost deafening report.

Some modern electrical machines have been made using plain vulcanite plates without any metal foil, and these have been found to give excellent results.

All these electrical machines are of scientific as well as historical interest, but they do not enter into the commercial applications of electricity. They produce what

we call an electrical discharge, and not the useful electric current of which we shall hear so much in the following pages.

If these electrical machines had remained our only means of supplying electrical energy, we should never have had any practical form of electric telegraph, the telephone would have been impossible, while electric light and electric motors would have remained unknown.

The first practical step was the invention of electric batteries; it will be of interest to see how this came about.

CHAPTER III

HOW BATTERIES WERE INVENTED

What the twitching of a frog's legs led to—A debt we owe to two Italian professors—The meaning of electric pressure—Can we store electricity?—Some early experimenters have an alarming experience—The true meaning of conductors and insulators.

WE have become so accustomed to the use of electric batteries that people seldom stop to ask how it was that the principle of these was first discovered.

The story is a very simple and interesting one. A little more than a century ago an Italian physician, Professor Galvani, made a series of experiments with one of those early electrical machines, such as described in the preceding chapter. He was studying the effect of an electric charge upon animal structures, and while experimenting he observed that the legs of a freshly killed frog were convulsed if they were placed near to the discharge of an electrical machine. Some writers believe this discovery to have been purely accidental, and they relate the story how some edible frogs had been skinned to make soup for Madame Galvani, who was an invalid, and that these frogs happened to be lying in the Professor's laboratory when he first observed this peculiar twitching. One

would not expect to find frogs, partially prepared for food, to be left lying about an experimental laboratory, especially when the master of the house was a doctor. It is more reasonable to suppose that Galvani, who was a professor of anatomy, would be purposely trying the effect of these discharges upon a lifeless frog. Be that as it may, there is no doubt that, after having once observed these convulsive kicks, he would proceed with further experiments, so that the next part of the story seems quite probable. Having passed a copper skewer through the limbs of a frog, Galvani was about to hang these up on an iron rail when, as soon as the copper touched the iron, he noticed the same convulsive twitching which he had previously observed to be due to the discharge of an electrical machine. A few further trials and Galvani would find that this phenomenon could be repeated at will. It was soon found that the best effect was obtained by touching a nerve in the frog's limb with a piece of zinc and a muscle with a piece of copper, and then as soon as the two free ends of the metals were brought together the convulsive kick took place, just as though the frog's legs had come back to life.

Galvani failed to give a correct explanation of the cause of this phenomenon. He attributed the twitching movement to electricity generated by the animal tissue itself, but the correct solution was suggested by another Italian professor (Volta). He maintained that the electricity was not in the animal, but was due to the contact of the two different metals being in touch also with the moist flesh. Volta was soon able to prove his assertion by making up a battery of pieces of dissimilar metals.

The word battery is here used in the same sense as one speaks of a battery of guns. Taking a number of discs of zinc and the same number of copper discs, Volta placed these in pairs of one copper and one zinc, each pair being separated from its neighbour pair by a wafer of cloth moistened with acidulated water. When the topmost zinc was brought into metallic contact with the bottom copper disc, by joining these together with a wire it was found that a continuous current of electricity was set up in the wire (see Fig. 1).*

Volta was able with his pile of discs to show an electric spark, but believing that he might still increase the effect, he placed each pair of discs in a separate vessel filled with acidulated water, instead of merely dividing them by a moist cloth. When these different couples were connected up as in Fig. 2, a very enhanced effect was produced. This second arrangement went by the name of "Volta's cells," and the diagram (Fig. 2) represents several cells coupled together, forming a "battery" of cells. It has become general to speak of one cell as a battery, but we have no more right to do so than to call one gun a battery of guns. One very often hears people speak of a galvanic battery, but it would be more appropriate to say a voltaic battery, for Galvani had no part in the suggestion of the chemical cell or battery, which is due entirely to Volta. It was, of course, Galvani's frog experiment that led Volta to make investigations which ultimately

* It was found later that the active pair of discs was not the pair in contact with each other, but that the chemical action giving rise to the electric current was between the zinc and copper disc which were separated by the moist cloth. Therefore if the topmost zinc disc (see diagram) and the lowest copper disc were removed, the electrical effect would remain the same.

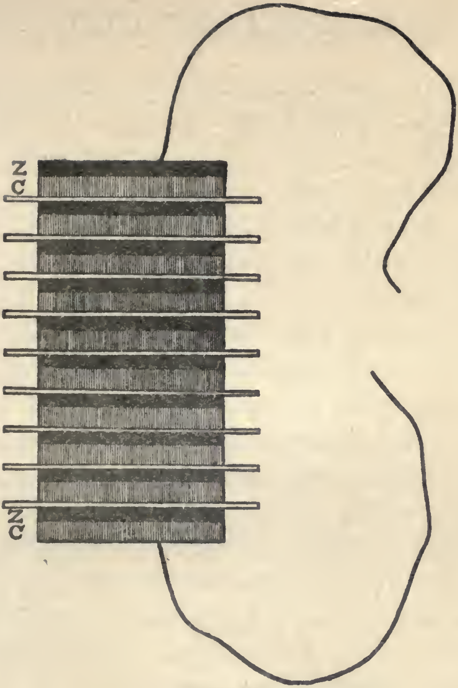


FIG. 1

THE EARLIEST ELECTRIC BATTERY

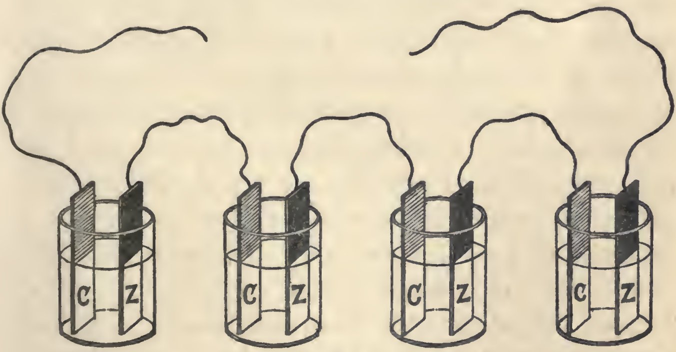


FIG. 2

VOLTA'S BATTERY OF CELLS

resulted in the voltaic cell, but Galvani was on quite the wrong track as regards the meaning of the frog experiment.

Surely we owe a great deal to both Galvani and Volta, for it is as though they had tamed the wild and fiery electricity of earlier times and made it behave in a more tractable manner.

The chemical cell or "battery" of the present day is very similar to Volta's earliest form. One battery in very general use consists of a piece of carbon and a piece of zinc immersed together in a glass jar containing a solution made by dissolving some sal-ammoniac (ammonium chloride) in water.

One finds very little variation in the size of these cells, and the reason is that no matter how large any particular cell is made, the electric pressure is always the same. The pressure or, as it is termed, the electro-motive force (E.M.F.) of a cell varies somewhat according to the metals and chemicals used, but it is invariably between one and two volts—the volt being the unit of pressure, as will be explained later. If we made a cell as large as the ocean we should still find the same low voltage. We should have an increased quantity at hand; but, without an efficient pressure to drive it through any resistance we put in its path, it would be of very little use for any practical purpose. We might have an immense reservoir of water harnessed to a water-wheel, but if the reservoir was situated at sea-level it would have no available pressure, and we could not get the water to do useful work. If we take a number of cells and form a battery by coupling together all the zincs and then all the carbons, we have still the

same result as far as pressure is concerned, for it is just as though we had one large cell; but if we couple the cells together, connecting the zinc of one cell with the carbon of the next, then we get the added pressures of all the cells. If we take four cells of two volts each and couple them as just described "in series," we obtain a pressure of about eight volts.

This question of connecting cells for pressure or for quantity is so often a stumbling-block that I have endeavoured to find some more expressive way of fixing the particulars in one's mind. If we picture what takes place in a single cell the matter may be clearer. Owing to chemical action in the cell a current flows between the free ends of the carbon and zinc, and if a wire join the two there will be a flow of electricity from the carbon to the zinc. If instead of connecting these two elements of the same cell together we lead a wire from the carbon of one cell to the zinc of the next, which is in the same condition as the zinc of the first cell, then we have a pressure of two volts from No. 1 carbon to No. 2 zinc, which will add on to the pressure now produced in the second cell, and so on. We thus obtain about eight volts from the combined pressures of the four cells, but there is a little loss owing to the power dissipated in overcoming the resistance offered to the current by passing through all the cells. If, on the other hand, we have the four separate cells as before, but connect all the zincs together, the zincs will all be in the same electrical condition. Since the electromotive force is the same in each cell the carbons will also be in the same electrical condition, and may be connected together. But we gain nothing in

pressure, the effect being the same as would be obtained with a single cell having a large zinc and a large carbon. But in this case the four cells offer less resistance to the passage of the electric current through them.

For almost all practical purposes we connect the cells "in series" to get the increased pressure required to overcome the resistance offered by the apparatus through which we wish to send the current.

Almost everyone now understands that we cannot create energy, but that we can merely transform it from one kind or form of energy to another. In our bodies we transform the chemical energy of our food into physical energy; we supply the muscles with, what is called, "inogen," which gives them energy to contract at our will, and if one mounts a bicycle he can get his muscles to transform this energy into a very apparent mechanical motion, and so on. If we cease to partake of food, we soon use up all the available energy, and as this "inogen" is produced at a certain rate, we may by continuous working use it up quicker than it is being produced, in which case we feel a lack of energy, and as soon as we thus become fatigued we should give our muscles rest to allow time for a further formation of inogen.

It is apparent that in the battery it is chemical energy which is transformed into electrical energy; and if we continue this process until the chemical action ceases, the transformation will also stop, so that it is necessary in time to add new exciting chemicals.

These batteries of cells are called primary batteries, as also are the "dry cells," which are now so much in demand. The principle of these dry cells is just the same

as in the simple cell already described, but the liquid is replaced by a moist paste for convenience of handling.

This seems a convenient opportunity of mentioning "secondary" batteries, more commonly called storage batteries or accumulators. A secondary cell may consist of two leaden plates perforated with holes which are filled in with red lead and immersed in dilute sulphuric acid. There is no chemical action between these two similar plates, so that we cannot call forth any electrical energy as we do from a primary cell. If, however, a current of electricity from another source is passed through this secondary cell, the chemical condition of the plates is found to be entirely changed, and strange to say, the change in each plate has been different. At the one plate peroxide of lead is formed, while at the other spongy lead is observed. It almost seems like a fairy tale to learn that when these two plates are now connected to each other by a wire the electricity appears to return from one plate to the other in the opposite direction to which it was passed through the cell, producing a steady electric current in the wire circuit. On further consideration it may seem less wonderful than the simple primary cell before described, for we have in this secondary cell merely made, as it were, an artificial primary cell.

In charging the secondary cell or accumulator, we have transformed electrical energy into chemical energy, which latter is really what we have stored, and which, as soon as the plates are connected by a wire, is again transformed into electrical energy. This can hardly be called storing electricity. As soon as the plates have worked

back to their normal condition they become inert, but they may be recharged and so on.

I think a good analogy may be found in the simple principle of the "old grandfather's clock." When the clock is standing with its weights at the bottom and showing no signs of energy, it is analogous to the secondary cell uncharged. The weights are then raised against the pull of gravity, and some physical energy is expended by the person thus winding up the clock. In the other picture this is equivalent to the charging of the cell, the electrical source disturbing the chemical conditions of the plates. Further, the clock weights, when released, in falling back to zero drive the clockwork, but as soon as they reach the bottom no energy is available; analogous to this is the joining of the plates by a wire through which a current of electricity flows until the plates have reached their normal condition, when no further available energy remains to be transformed. As already remarked, it is chemical energy that is stored in these accumulators, so that we can only speak of storing electricity indirectly.

Can electricity be stored? This question naturally arose in the minds of even the earliest experimenters. These men were getting certain effects from their "rubbing" machines, and it was reasonable to suppose that if they could only store up a quantity of electricity they would get a greater effect. It had been discovered that glass offered a very great resistance to the passage of electricity, so it was suggested to try and charge some water in a glass jar, and thus prevent the accumulated electricity from escaping. Several experimenters appear to have been at work in this direction at the one time,

and in the University of Leyden (Netherlands), while this experiment was being carried out, quite an alarming incident occurred. The water having been charged, the person holding the glass jar very naturally took hold of the metal which had been conveying the charge to the water, in order to disconnect it from the machine, but whenever he touched this he received a severe shock through the arms and breast. In this way it was discovered that if a conductor is charged inside a glass vessel, and having another conductor outside, as soon as the conductors are connected together there is a sudden discharge of the accumulated electric strain. In the original experiment the water formed the inside conductor, while the experimenter holding the jar was the outside conductor, but "Leyden jars" were constructed, using a tinfoil coating both on the inside and the outside of the glass, carrying the foils about half-way up the jar. A metal connection on an upright rod is placed inside, and it is then convenient to discharge the jar by a pair of discharging tongs, touching the outside tinfoil with one prong and bringing the other near to the metal upright, when a vivid spark is seen at this point. By having the metal coatings of the Leyden jar removable, it may be shown that the electric strain is stored in the glass and not in the metal coatings.

It may be of service to remark at this point that all bodies will conduct electricity, provided the current has sufficient pressure to overcome the resistance offered to its passage. The difference between the conducting properties of some materials, however, is as great as is a drop of water to a mighty ocean; or perhaps a better

analogy would be to say that while a pipe or tube will conduct water, a solid log of wood will also do so, but in a very different degree. The metals are very good conductors of electricity, silver and copper being the best; and being very nearly equally good, copper is, of course, preferred for economy, and it is this property of copper which has so increased the demand for the metal during the last half-century. Glass, india-rubber, cotton, and silk, are all such poor conductors that they have been termed non-conductors or insulators. Between the metals and these come some materials which are neither good conductors nor good insulators; and it must be borne in mind that these terms are merely comparative, for a substance might be a conductor for one purpose and an insulator for another. A heap of sand may be sufficient to stop a tiny streamlet on its way to the ocean, but something more would be required to stop the same amount of water issuing under pressure from the nozzle of a hose-pipe.

When two bodies are said to be put into metallic contact with each other, it simply means that they are connected together by a wire, or other piece of metal, which offers a conducting path through which electricity may be caused to pass from the one object to the other.

What about the electric pressure of an accumulator? It is the same humble story of about two volts per cell; an increased pressure is obtained, just as in the case of the primary battery, by connecting the plates of different electrical conditions together. These secondary batteries are not only of great use as reservoirs, but they give a uniformly steady current, whereas the current obtainable

from a primary battery is very intermittent, owing to hydrogen gas collecting on the carbon plates and interfering with the passage of the current. Primary batteries are all right for electric bells, telephones, etc., where there is not a continuous call upon their energy, but the accumulator is necessary where a constant current is desired.

CHAPTER IV

WHAT IS MAGNETISM?

One magnet's strange behaviour towards another—How a magnet is affected by a neighbouring electric current—A magnet that will attract and let go at will—What takes place in a piece of iron when magnetised—Experiments that go to prove an interesting theory.

FROM our childhood we have all had some knowledge of magnetism in connection with the compass needle, and no doubt many of us gained further knowledge from magnetic toys presented to us to enable us to become expert anglers. In any case it is scarcely necessary to remark that a magnet attracts iron, or that a light magnet balanced upon a pivot will have one end or "pole" pointing north and the other south.

There is a third and a very remarkable property of magnets; a simple one and yet one that often leads to confusion. Every magnet has, of course, a north and a south-seeking end or "pole," and these two ends are usually brought close together by making the magnet in a horse-shoe form, in order to have the attractive pull of both poles combined. It is more convenient for experimental purposes to make the magnet in the form of a straight bar, so that the effect of each pole may be examined by itself. In order to distinguish the poles it is customary to mark the north-seeking pole with the

letter N, or to paint that end or mark it in some way so that it is quite easy to discern the north pole, while the plain end is, of course, the south.

If the north pole of a bar-magnet be brought near to the north pole of a magnetic needle pivoted upon a stand, the north pole of the needle will fly away from the north pole of the bar-magnet, but the south pole will come round and be attracted. The south pole of the magnet and the south pole of the needle will also repel each other, but the two unlike poles will always attract one another. This is certainly very strange—the poles all look exactly alike and they will all attract iron equally well, but their behaviour towards each other is so different; the norths will have nothing to do with the norths, the souths are equally repellent to one another, but a north and a south are always attractive to each other.

It is most important that the true facts of the case should be impressed upon our minds. Many years ago in delivering a popular lecture I had demonstrated these simple facts experimentally, and to my way of thinking the matter seemed quite clear, but when the chairman, who was the possessor of several university degrees, made some remarks in proposing a vote of thanks I got quite a big surprise. He said that personally he had gained a great deal of information from the lecture, and that it was remarkable how little outsiders knew about these matters; he had not even known till then that a magnet attracted iron with one end and repelled it with the other. Needless to say the remark was decidedly disappointing, but a brief repetition of the experiments

served to show that a magnet attracts iron equally well with both poles, and that the repulsion only takes place between the two similar poles of two magnets. I have often observed this misunderstanding during conversation, and quite recently I find the author of a widely circulated book going astray on this same point.

If two north poles repel each other, how, then, is the north pole of a compass needle attracted by the north pole of the earth? In point of fact the end of the compass needle pointing to the north is of opposite polarity, but it would be confusing to call this north-pointing end a "south" pole, although the Chinese and the French have done so. We prefer to call it the north-seeking pole, or, in short, the north pole, but it must be remembered that the true meaning is the north-pointing or seeking pole. One does not see any magnet in the modern mariner's compass, as the compass card itself is pivoted at its centre, and has a number of small magnets fixed to its underside, so that the card itself takes up its correct position, indicating the different cardinal points. In this way there can be no confusion, as was sometimes the case previously when an inexperienced person could not tell whether the painted or the plain end of the needle was the north-seeking pole.

If two bar-magnets are used together, having the two north poles and the two south poles respectively touching each other, then a more powerful magnet is the result, as one would quite anticipate. If, however, the relative position of the magnets to each other be reversed, so that a north pole and a south pole lie in contact at each end, all trace of magnetism disappears. One cannot now

even lift a small iron nail with these two magnets, but when separated again they are each just as attractive as before. We have almost ceased to wonder at this strange fact, but it is none the less remarkable for that, and it will be seen in the subsequent chapters that the peculiar behaviour of these magnetic poles to each other is of the very greatest importance to us in practice.

While the early experimenters had been able to make magnets by rubbing pieces of iron with a natural magnet or lodestone, and while they also had observed a piece of "rubbed" amber attracting light bodies to it, there is doubt if it ever occurred to them that there might be any connection between magnetism and electricity. Later on the idea did become definite, and during the year in which our late Queen Victoria was born (1819) a Danish professor (Hans Christian Oersted) found that a magnetic needle when brought near to a copper wire carrying a current of electricity behaved in a strange fashion. The magnet found the wire of more attraction than the north and south poles of the earth, so that it would no longer act as a compass needle while it remained in the neighbourhood of an electric current. If the magnet is placed above or below the wire, the magnet will swing round and take up a position at right angles to the wire. Whether the north pole of the magnet comes out to the right hand or to the left hand depends upon the direction in which the current is flowing in the wire.

In the accompanying photographs a magnetic needle is first shown standing at rest in the neighbourhood of a copper wire in which no current is flowing. In the second photograph the wire is connected to the battery so that a

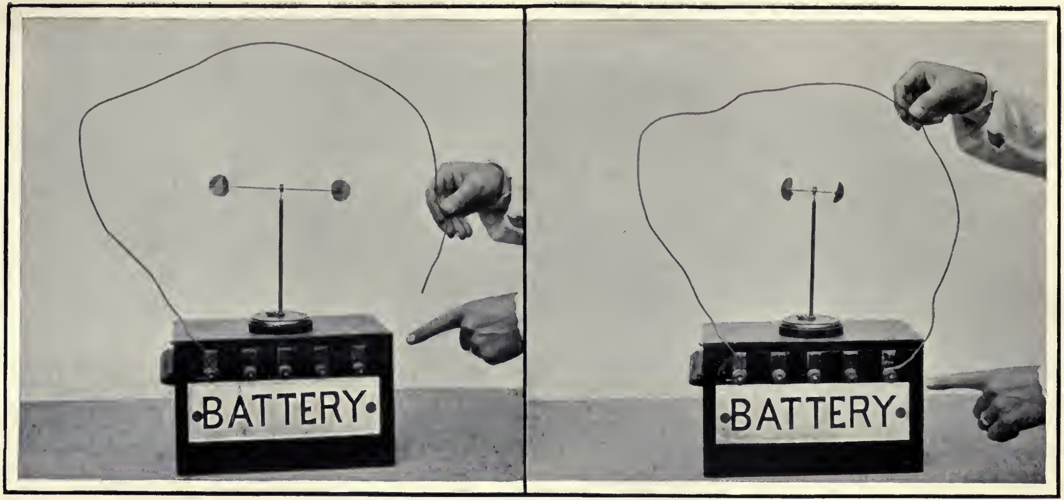
current of electricity passes along the wire, and the effect of this neighbouring current is to cause the magnet to turn round and take up a position at right angles to the wire. In the photographs the little magnet has a round paper disc attached to each end in order to show its position more clearly.*

For the present it will be sufficient to note that if we send the current along the wire in one direction the north pole of the needle swings out to the right hand, and when we send the current in the opposite direction the north pole of the needle turns out to the left hand.

The needle and the wire may be fixed in a vertical or upright position, and the result is the same. If instead of a single wire passing above or below the needle the wire be continued round and round to form a coil, the result is greatly enhanced. This exceedingly strange attitude of the magnet towards the electric current is of immense importance to us, as we shall see later.

After this connection between electricity and magnetism had been discovered, experimenters would naturally wonder if the current had any effect upon iron that had not been magnetised. Very soon a French scientist, François Arago, was able to show that the wire carrying an electric current did affect small filings of iron. The filings each appeared to become a little magnet, and if a

* In passing I would commend this method to any chance reader who is accustomed to lecture in physics. I recently saw a very beautiful experiment in one of our Universities completely spoilt owing to a lever being so fine that its movements could not be seen at any distance. A small disc cut from light tissue paper would not have hampered the movement of the lever, and would have enabled the audience to follow its eccentricities with ease.



When an electric current passes along a wire it sets up a magnetic influence around it, so that a magnetic needle placed in its neighbourhood, as in the left-hand illustration, will turn round and stand at right angles to the wire whenever the current is sent through the wire, as is shown in the right-hand illustration. This simple phenomenon is the basis of nearly all modern applications of electricity. It is the intimate connection between electricity and magnetism that makes it possible to have telegraphs, telephones, dynamos, electric motors, etc.

quantity of filings was placed in a glass tube and a strong current was sent through a wire wound around the tube, the tube of filings became quite an appreciable magnet. If a piece of soft iron, instead of a tube of filings, was placed inside the coil of wire carrying a current, the iron became quite a powerful magnet, but as soon as the current ceased in the wire the magnetism disappeared too.

If one takes an ordinary kitchen poker and wraps an insulated wire round and round it from one end to the other, whenever the two ends of the wire are connected to a battery the poker becomes a powerful magnet, and will support pieces of iron, such as keys, scissors, nails, etc. As soon as the current is stopped in the wire by disconnecting it from the battery, down tumble all the objects, for the magnetism has vanished from the poker. Here we have a most useful kind of magnet, which will attract or let go at will; and such magnets or electro-magnets are of the very greatest importance to us in telegraphs, telephones, dynamos, motors, etc.

Electro-magnets are made of soft iron, but if hard steel were substituted inside the coil of wire, the steel would be much slower in replying to the influence of the current, and when the current was stopped it would be found that the magnetism remained, and the wire could then be removed. The steel magnets thus made are called permanent magnets, to distinguish them from electro-magnets, which are merely temporary. The magnetic needle in the compass is of course a steel magnet, as also were the toy magnets of our youth.

Iron, like all other substances, is built up of very small particles, called molecules, which are so exceedingly small

that they are far beyond the reach of the most powerful microscopes. Of course, we must magnify these molecules immensely in our minds when we think of them, no matter how small we try to picture them.

Each of these molecules of iron is itself a tiny magnet, having of necessity a north and a south pole. In the iron these are all lying higgledy-piggledy, the pull of one counteracting the pull of another, so that no trace of magnetism is found in the iron.

It has already been shown that a magnet inside a coil of wire will turn round and set itself at right angles to the coil whenever a current of electricity is passing in the wire. Therefore, each molecule in the iron core of the electro-magnet will behave in the same fashion, for each molecule being a tiny magnet will turn round and set itself at right angles to the wire, with its north pole in one direction and its south pole in the opposite direction. All the combined north poles of these midget magnets now acting together produce a very effective power of attraction, as also do the united forces of the south poles. Thus at the one end of an electro-magnet is found a north pole and at the other end a south pole, no matter whether the magnet be a straight bar or bent in horseshoe form.

It is quite reasonable to suppose that in hard steel these tiny molecules are so firmly bound together that when the current once gets them turned round they cannot readily swing back again, in which case we have a permanent magnet. On the other hand, in soft iron the molecules will reply much quicker to the controlling current, but will only remain with their north poles all in

one direction as long as the neighbouring current holds them there; as soon as the current is withdrawn they swing back to their normal higgledy-piggledy condition.*

One may imagine the turning on of the current to be, in military parlance, the command of "Eyes front" to this regiment of molecules; the withdrawal of the current to be the "Stand at ease" or "Stand easy."

If this generally accepted theory of magnetism be correct, then one can foresee what will happen if a so-called permanent steel magnet be raised to a red heat. As its molecules will be set in rapid vibratory movement they will be given an opportunity of freeing themselves from the artificial position into which they were forced by the effect of the electric current. This exactly corresponds with what does take place, for no trace of magnetism is found in the "permanent" magnet when it has been thoroughly heated. For the same reason one must be careful not to knock these steel magnets about, for by hammering them one may assist the molecules back to their normal positions.

Strange to say, when a piece of iron rod is magnetised it becomes longer and thinner, but this is quite in keeping with a turning movement provided the molecule is of irregular shape. The metals nickel and cobalt are also magnetic substances, and indeed it appears as though all matter is more or less magnetic, but iron stands out head and shoulders above all other materials in its magnetic properties. It has been found possible, however, to pro-

* It is not necessary to suppose a real topsy-turvy condition, for if the tiny magnets were forming complete magnetic chains or rings the absence of any outward effect would be just the same.

duce alloys of copper, manganese, and aluminium, which have proved much more magnetic than nickel and cobalt, though falling far short of iron.

It is quite possible to magnetise a piece of steel by the earth's influence, if the metal is placed in a definite position in relation to the magnetic poles of the earth and then hammered in order to give the molecules an opportunity of getting into position. Steel railings after standing for many years in one position have often been found to be quite appreciable magnets, as also have steel rails of a railway track.

CHAPTER V

HOW MAGNETISM IS RELATED TO ELECTRICITY

A magnet without any iron—A British scientist makes a simple discovery which leads to great things—Some absurd mistakes between magnetic and electrical attraction—How the iron molecule possesses magnetism—Some notable examples of perpetual motion—What happens to the molecule when highly heated—A military analogy.

WHEN magnetism and electricity were at first known there was not supposed to be any connection between them; then for a time they were treated as sister sciences, while now one would feel it more natural to have but one scientific name to distinctly include both.

In the preceding chapter we saw that an electric current flowing in a wire around a piece of iron produced magnetism in the iron. If the iron is withdrawn altogether, it will be found that the coil of copper wire is itself a magnet, as long as the current flows in it.

If a light coil of fine insulated copper wire be freely suspended, and attached to a battery, it will be found that the coil, with the current passing through it, behaves exactly like an iron magnet. One face of the coil will be attracted by the north pole of a bar-magnet, while the other face will be repelled, showing that the coil has

a north and a south pole. When a piece of iron is placed inside the coil the effect is greatly increased.

We see that an electric current produces a magnetic field * in its neighbourhood. A piece of ordinary iron, when placed in this field, becomes a magnet. Therefore if we possess an electric current we may produce magnetism in a piece of iron.

In the foregoing statement we see a very close relationship between electricity and magnetism, but this is not all. We shall see that if we have a magnet we may obtain an electric current in a neighbouring coil of wire.

It was some seventy years ago that our great British scientist, Michael Faraday, discovered that when a coil of wire was quickly moved between the poles of a magnet, an electric current was set up in the wire at each movement.

We have all seen this experiment repeated in those small magneto-electric machines, in which one drives a coil of wire round in the magnetic field of a permanent magnet. Such machines are sometimes used for medical purposes, but perhaps more often for amusement.

This very simple little experiment of Faraday's in time gave birth to our gigantic dynamos and motors, and when we think of all that these mean we shall surely not fail to put a true measure of value upon the patient research work of scientific men.

Many people make a strange confusion between the meaning of magnetic attraction and the attractive power of an electrified body. I remember a student, when replying to a question as to how one may magnetise a piece

* A magnetic field means a space in which we find magnetic force.

of steel, writing down in all seriousness, "Rub it with a piece of silk or flannel," showing that he had confused magnetic attraction with the electrical attraction exhibited by an "excited" glass rod, etc. Equally absurd was another instance, which happened at the close of a lecture to young people. I had demonstrated electrical attraction by "charging" a young girl by means of an electrical machine, and then showing her hair attracted to my hand when held over her head. When the lecture was over I noticed a young electrical engineer-elect place a girl upon the insulated stool, but not in connection with any source of electricity, and then merely holding a large steel magnet over the child's head, he was quite surprised to find that her hair did not rise to the occasion, he attributing the failure to dampness of the glass legs of the stool. These are extreme cases, but they illustrate a difficulty that cannot exist if one realises that a magnet attracts only iron to any appreciable extent, whereas an electrified body will attract any substance.

The coil of wire carrying an electric current is not an electrified body. One may picture an electrified body as having a charge of electricity at rest in a strained condition, while a body conveying a current has electricity in locomotion.

In the molecular theory of magnetism, briefly explained in the preceding chapter, it is obvious that the question as to what magnetism is has only been answered in part. This theory does not go to the root of the matter, as it sets out with the assumption that each molecule of iron is itself a magnet. Where does the molecule's magnetism come from? It is supposed that there is electricity in

motion around the atoms of iron, and that each miniature electric current sets up a tiny magnetic field. It will be understood that a molecule is merely a group of atoms. The iron which we see is in reality a great congregation of these invisible molecules. Therefore the iron has within it a myriad of miniature magnets. When these are all acting unitedly, the lump of iron shows very appreciable signs of magnetism, but when these tiny magnets are all at sixes and sevens, there is no outward sign of magnetism.

We may picture a lump of iron, in the latter condition, being placed within a coil of wire in which an electric current is flowing. All the tiny magnets wheel round into the one position, and we say that the iron has become a magnet. It will be observed that the magnetic force was existent already within the iron, and that the influence of the neighbouring electric current merely set these tiny forces in order.

If we place a piece of gold or silver within the electric coil, we do not get any signs of magnetism in these metals, because they do not contain the myriads of magnetic atoms which we find always in iron. However, we have seen in the preceding chapter that alloys of certain non-magnetic substances such as copper, manganese, and aluminium have shown quite respectable signs of magnetism when treated in the same way.

There is one point which is worth mentioning. We used to say that iron could be magnetised to a certain extent and no further. This was called the *saturation point*. The mental picture we formed in those days was that of soaking magnetism into the iron till it could hold

By permission of Wilhelm Fulle, Barmen.

A SUSPENDED ELECTRIC RAILWAY

This railway at Elberfeld, in Germany, which carries passengers above the river and streets, shows a principle that was proposed for carrying light railways across very rough countries. The cars carry electric motors, which receive the current from the overhead track.

no more. Now we have a much more reasonable picture. As the magnetic force resides already within the iron, it is quite clear that we can get a certain degree of magnetism and that we can get no more from the iron, no matter how powerful an electric current we use. It will be clear also why a piece of soft iron, when placed within a coil carrying an electric current, increases the magnetic field. The iron adds to the magnetic field the magnetism which is already locked up within the iron.

We shall be able to form a much clearer picture of the nature of magnetism when we come to consider the present ideas concerning electrical phenomena. In the meantime we are quite able to step out into the world of practical electricity. There we shall find that all the great uses to which electricity has been put are merely applications of the simple phenomena set forth in the preceding chapters.

CHAPTER VI

HOW WE CAME TO HAVE THE TELEGRAPH

A Highlander's amusing explanation—Man's earliest method of signalling — The first really practical electric telegraph—An American rival which came to stay—An instrument to record the telegraph signals received—Why a complete circuit is required for an electric current—How one wire can now be used.

THERE is an amusing story in connection with the early days of the telegraph which, whether real or fictitious, will serve to illustrate a point of much importance. One Scottish Highlander is said to have asked another how the telegraph worked, whereupon the second one replied that he didn't understand it but he thought he could explain it, from which remark one would infer that he had some Irish blood in him. Finding a convenient illustration in his faithful collie, he asked his friend to imagine the dog stretching itself and yet stretching itself until its head reached Glasgow while its hindquarters remained in Oban. If he were then to tramp upon the dog's tail it would bark at the Glasgow end, but he was careful to add that as it was not very convenient to stretch a dog so great a distance, the telegraph folk put up a piece of wire which seemed to act just as well.

While the Highlander's explanation may not make the details of electric telegraphs very clear to us, yet there is one point in the story which cannot be too well emphasised, and that is, that there is a medium of communication between the two places, and this there always must be, even in the case of wireless telegraphy.

Early in the world's history man found it necessary to be able to signal to a distance, and so he adopted the method of lighting beacon fires upon the hill-tops, and these signals could be passed on from one point to another. Of course these men in ancient times had arranged with their distant friends that when a fire was seen upon the hill-top it would mean a certain thing. When we moderns wish to communicate with our friends at a distance we have to use prearranged signals in the same way. We find it convenient still to use visual signals for military and naval purposes, such as by the waving of flags. All such systems are limited necessarily to very short distances.

When one sees a magnet turning first to one side and then to the other, according to the direction in which an electric current is sent through a coil, it is a very natural step from that to the first practical electric telegraph instrument. It is apparent that if one person had the coil and magnet in his house and another had the battery at his home, while the wires still connected the battery to the coil the second person could cause the magnet beside the first to move to one side or the other at will, and by an agreed code intelligible signals could be transmitted.

The needle telegraph is just this coil and magnet and nothing more, except that it is put into a more convenient

form. The magnet is fixed to a spindle passed through its centre, and is then mounted in a vertical position at the back of an upright board; the coil is then placed around it, leaving the needle free to fall to right and left. Then, so that the movements of the needle may be readily seen, an indicator or dummy needle is fixed on the other end of the spindle, which comes through to the front of the board. This indicator or needle moves, of course, along with the magnet at the back, and so the signals are clearly read. An arrangement for reversing the current at will, in order to move the needle to one side or the other, is added, and this may be operated by moving a handle from left to right, or by depressing one or other of two small levers or "keys."

It might be a matter of agreement to signal one movement of the needle for A, two for B, and so on; but the operator would very soon weary of this plan if he had many letters far on in the alphabet to count out. Imagine our written language being constructed thus:—I for A, II for B, III for C, and so on. It is much more convenient to let two strokes leaning against each other with a third stroke crossing them stand for A, three strokes placed thus for N, thus for Z; and so in telegraphy it is agreed that if the needle is moved once to the left and then once to the right (\ /) this will signify A. It is quite remarkable that in order to construct the whole twenty-six letters of the alphabet by combinations of these two movements we never require to move the needle more than four times for any letter. It evidently did not occur to the experimenters at the outset that this could be done, as they made the early instruments with five

needles in order to get a greater variety of signal, their idea being to make the needles point out the letters on a dial.

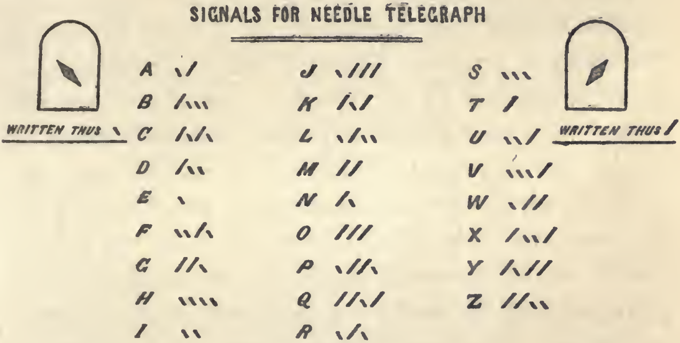


Fig. 3

Referring to the accompanying alphabet, it will be seen that the letters most often in use get the advantage of the simplest signals. Once to the left stands for E; once to the right for T; and so on. It is usual to print the left-hand strokes shorter than the right-hand ones, as shown; but this is merely for convenience of space.

Our own alphabet is of very simple construction; give a boy four straight strips of cardboard, each representing a stroke, and he can with these construct more than half the alphabet, while a few semicircular pieces added will enable him to complete the whole twenty-six letters.

While Cooke and Wheatstone were the first (1837) to set up a needle telegraph in this country, we cannot claim the invention for them, as Professor Ampère, of Paris, had suggested fifteen years earlier that a magnet and coil placed at any distant point of a circuit would

serve for the transmission of signals; and other experimenters in Germany had actually carried this out with success.

Simple as this method is, there was a yet simpler plan adopted in New York about the same time as the former was set up in London. Knowing that an electro-magnet would attract and let go at will, a piece of iron was suspended by a spring so that it stood close over the poles of the electro-magnet. Whenever a current was sent along the wire to the electro-magnet it would attract the iron and hold on to it as long as the current was left on, but as soon as the circuit was broken the magnet lost its power, so that the iron was pulled away by the suspending spring. The movable piece of iron was mounted on one end of a small lever, the other end of which worked between two stops, so that each time the iron armature was attracted downwards it caused the other end of the lever to "click" against the upper stop, and by this means signals or intelligible "raps" were made. If the lever clicked against the upper stop and then immediately fell back on to the lower stop, that indicated the letter E, but if after striking the upper stop it remained a little before falling back on the other stop, then the letter T was signalled. If the lever gave three quick successive clicks the letter S was to be understood, and so on.

This method saves the trouble of reversing the current which was necessary in the needle telegraph; all that is required in this American invention is to make and break the current's path. While this system of telegraphy had been suggested by a great American scientist, Henry, as early as 1831, it was not till 1837 that another American,

Morse, brought the instrument into practical use. Working by clicks it is called the "morse-sounder." Morse also arranged that the instrument should record the signals received by marking them on a strip of paper, and this has been termed a "morse-inker." If one end of the armature lever is fitted with a small wheel, which

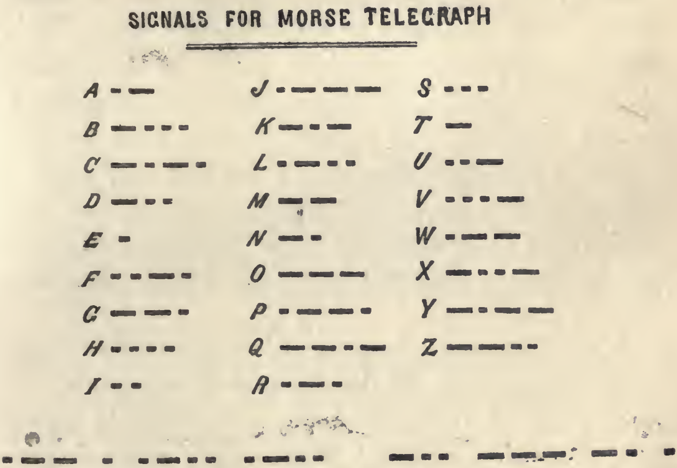


Fig. 4

when at rest dips into a small ink-well, and if, instead of coming in contact with a stop when raised, the wheel touches a paper ribbon, which is kept in motion by clockwork, then a mark will be made along the centre of the paper as long as the wheel is held up by the magnet at the other end of the lever. It is therefore an easy matter to make long or short strokes at will by keeping the current on for different lengths of time. That is all this instrument can do, make short and long strokes, usually called dots and dashes, and the alphabet is made

up by different combinations of these. The letters E and T being used oftener than any other letters get the advantage of a single short stroke for E and a single long stroke for T, as will be seen from the accompanying alphabet. It will be noticed on comparing the Morse and the needle alphabets that they are really identical; a short stroke or "dot" being equivalent to the needle falling to the left, and a long stroke or "dash" to a needle movement to the right hand. With constant practice this alphabet becomes as natural to the operator as our everyday A B C, and I have heard of two telegraph operators carrying on a silent conversation with each other by a slight movement of the left and right eyes. Underneath the Morse alphabet (see p. 57) will be found a short sentence of two words, which may easily be deciphered.

A bald statement that an electric current must always have a complete circuit does not appeal very forcibly to many minds. I have seen people quite at sea in trying to arrange a simple electric circuit, such as connecting up a bell, push, and battery. There need not be the very slightest confusion if one clearly keeps in mind what is taking place when a battery sends a current of electricity along a wire. All that the battery does is to cause an electric current to pass from its carbon plate to its companion zinc. We fix a short wire across from the one plate to the other, and an electric current passes along the wire on its way from the carbon to the zinc. We may make the wire a mile long, or as long as we please, and the current must pass by this route on its way from the one plate to the other. If we carry the wire to

Land's End and back, then before the current can get from the carbon to its close neighbour the zinc plate, it is forced to travel *viâ* Land's End. If the wire circuit is broken at any place the current immediately ceases, as it has no path left from the carbon to the zinc; if the wires are touched together again, the current once more passes. The ordinary electric bell push is merely a means of making and breaking the circuit.

If the wire of our imaginary Land's End circuit be cut at that distant place and the two free ends be joined to the two ends of the coil in a needle-telegraph instrument, then the current in going from the carbon to the zinc in the battery has to pass through this distant telegraph instrument, as its coil has become part of the circuit. The necessity for a complete circuit is therefore quite apparent (see Fig. 5).

While fitting up a telegraph installation on a railway in 1838, Steinheil, of Munich, noticed that his return wire was broken, and the two ends were put into the earth; the current passed just as though the wires were joined together. It was soon found that it did not matter how far distant these earth connections were, so that if a telegraph is to be fitted up between London and John O'Groat's a wire is led from the carbon in the battery at London all the way to that northern limit of the Scottish mainland and there connected to one end of the telegraph coil. Instead of now bringing a return wire from the other end of the coil right back to the zinc of the London battery, a short wire is simply connected to the earth at the Scottish end, while at the London end another short wire is led from the earth to the zinc in

the battery there. At the London end it would be quite sufficient to fasten the short wire from the zinc to any water-pipe in the building and thereby get into contact with the earth, but not finding a similar convenience at

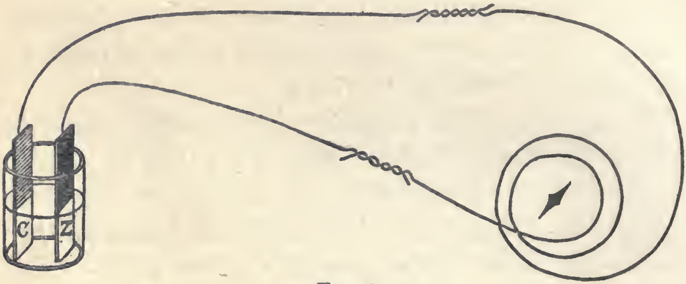


FIG. 5

SHOWING A CELL CONNECTED TO A TELEGRAPH INSTRUMENT

the northern house it would be found necessary to attach the wire to a copper plate and then bury it in the moist subsoil. In Fig. 6 an earth circuit is shown in which both ends are attached to buried plates.

It was originally supposed that the current of electricity passed through the earth from the one plate to the other, but it seemed afterwards more reasonable to picture the current as being dissipated in the earth at the one end and fed on at the other end. An analogy portrays the earth as a great ocean, the wire like a pipe with its two free ends dipping into the ocean at far separated points, and the battery as a pump propelling the current along. Whatever mental picture we form, we must remember that the electric current is not a material fluid.

There is no difficulty in sending a current over this

single wire with its earth circuit, but one is not surprised to learn that when any great natural disturbance takes place in this ether-ocean into which the wires are dipping,

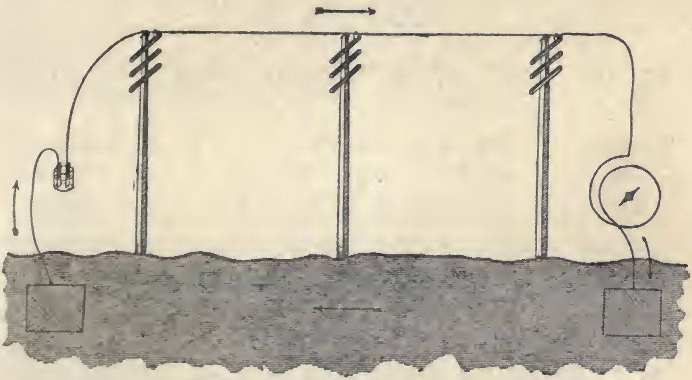


FIG. 6

HOW A TELEGRAPH IS WORKED WITH A SINGLE WIRE

the current in these earth-connected wires is very appreciably affected, our whole telegraph system being sometimes quite upset during a magnetic storm.

CHAPTER VII

HOW WE NOW SEND TELEGRAMS

Beginning of public telegraphs—A telegram outruns a murderer—Impetus to telegraphs—Government takes control—A country postmaster baffled—Speech wired in half the time of delivery—How high speeds are attained—How a failing current hands the signals to a vigorous current—Several messages pass simultaneously on one wire—Some clever inventions—Ordinary writing by telegraph—Typewriting telegraphs—Enormous telegraph business—Telegraph *versus* telephone.

WHEN His Majesty the King was born, in 1841, the good news was not heralded across the country by the telegraph, for the very good reason that not a single telegraph line connected any two towns together, the invention having only been applied to a few short private lines along the railways.

In the United States things were in very much the same position, the first commercial line of telegraph not being opened until 1844, when Washington was connected with Baltimore.

One would have expected this great invention to be received by the people with open arms, but in this country the inventors could not get anyone to take an interest in the matter excepting railway companies, which were at that time few in number, so that the first five years' working entailed a serious loss to the inventors. How long things might have continued in this way but

for a chance incident it is difficult to say, and indeed one would not have been surprised to learn of the inventors determining to abandon the scheme and lose no more money. It so happened that a Quaker, having committed a murder near Slough, fled to the Great Western Railway and took train to London, but the news of the dreadful deed reached the station at Slough soon after his train had left. One can imagine the disappointed pursuers possibly thinking "a miss is as good as a mile," for no living being could hope to overtake the train; but someone suggested getting the railway officials to send word over their telegraph line to London. A full description of the Quaker and particulars of what had happened were spelt out by the needle telegraph, so that the murderer, while no doubt congratulating himself that he had outrun any chance of arrest, was startled to find that news of his crime had reached London before him, as he was "shadowed" on his arrival and quietly arrested.

One can imagine the news of this wonderful capture spreading through London and from town to town till the country began to praise the telegraph as a right useful messenger. Investors, who had previously looked upon the electric telegraph as too risky a business, would now be most willing to give financial support. The Electric Telegraph Company was soon formed, and within three years about 1,500 miles of wire were erected, and before our King was eight years of age, London, Birmingham, and Manchester were in direct communication by telegraph. It was not long before other private companies were formed.

A telegram in those days meant important news; even the wealthy would not have thought of wiring such messages as "Will come to see you to-morrow afternoon; wire if convenient," for such a telegram would have cost four or five shillings, even for a short distance, while the minimum charge between London and Edinburgh or Glasgow was twelve shillings.

After about ten years' working, one of the telegraph companies tried to adopt a universal rate of one shilling, but the opposition of the other companies was too strong. Five years later all the companies agreed to a big reduction in rates, with the idea of increasing business, and this proved a great success.

It is very well that the Government took over the telegraph business in 1870, for it was only natural that the private companies would not extend their telegraph lines into districts where they could not hope for a profitable return. The Government could afford to take a less mercenary view, and small towns and villages soon had their post offices connected by telegraph with the nearest large town, till now a perfect network of wires extends across the country in all directions.

It is impossible to over-estimate the value of the electric telegraph to the world, and yet it would not be surprising to find some people willing to denounce this invention as the destroyer of the once peacefully-quiet life of the "good old times." There is no doubt that the electric telegraph and the steam-engine are the two chief factors in producing the hurry-scurry of the present day; but surely it is quite unnecessary to set forth the very great advantages which these inventions have brought into our

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Telephone and Air-Helmets used by Fire Brigades. The wires are carried inside the pipes, which also convey the fresh air. The telephone enables firemen in a burning building to communicate with an officer in the street. Powerful electric lamps may be seen in the men's hands.

everyday life by putting us in touch with all the ends of the earth.

The speed with which intelligence could be conveyed to a distance by the electric telegraph, as compared with all previous methods, was so very great that the actual time required in manipulating the instrument was at first counted of small moment; but with the consequent hastening of business methods and the extended use of the telegraph system, a great deal of attention was soon given to means of increasing the speed at which messages could be despatched.

In country districts there may still be found some of the A B C dials, by which a word is slowly spelt out by causing an indicator to move round a dial and point out the letters of the alphabet separately. I remember many years ago going into a little country post office to despatch a telegram, and being informed by the elderly "postmaster" that he couldn't get his machine to work. He explained that it had just been fitted up, and that he found they had given him no bottles to work it with, such as he had seen at a neighbouring village. I suggested that possibly his "machine" didn't require any bottles, which proved to be the case, as he had one of those A B C dials in which no battery is required, the current being obtained by driving a little magneto machine in exactly the same fashion as one rings up on a telephone. Of course, the advantage of these instruments for country districts was that the operator required to learn no special code or alphabet, but these would only be tolerated now where speed is of little consequence.

Even the needle telegraph, which is purely an English

instrument, is much too slow and is only used now for small districts and in signal-cabins on the railway.

The Morse "sounder," described in the preceding chapter, is almost universally used both in this country and in the United States for ordinary business. As it is necessary for the operator to spell out each word, and space the dots and dashes correctly, it will be apparent that even in the hands of a skilled expert the time taken in sending a message must be very much longer than the time required to speak the words. One might easily speak 180 words in a minute, but an operator could not signal more than thirty-five words comfortably in the same time, so that a two hours' speech delivered in Parliament, when telegraphed, would occupy a line from London to another important centre for a whole night, which would be a serious matter for the economical working of the Post Office. Fortunately this is not necessary, and although it may seem incredible, it is a fact that a two hours' speech may be passed over a single line in less than half the time taken to speak it.

While the speech is in progress the reporters may hand their "copy" to operators, who prepare a paper-ribbon in a punching machine, making holes to represent the Morse signals. With a full staff of reporters and operators, the whole copy of the speech may be thus ready on the punched ribbon almost as soon as the delivery of the speech is finished, and it is only necessary then to run this paper by clockwork through a special transmitter, thus causing the makes and breaks of contact, by means of the perforated holes, at a speed far greater than can possibly be done by the quickest expert's hand. The

Wheatstone automatic sender, which is in general use, can easily transmit at a speed of from 250 to 400 words per minute, the former figure being counted a fair working speed over a distance.

It is in connection with the automatic transmitter that the "morse-inker" is chiefly used to receive the signals, but the latter may, of course, be worked by an ordinary hand key as well. If an automatic transmitter were merely sending signals to a "morse-sounder," it would be quite impossible to read the clicks by ear. If they were coming in at a speed of about 300 words per minute, then there would be as many as 4,500 clicks made against the upper stop in one minute, which is equivalent to seventy signals in each second of time. Therefore, without the morse-inker the automatic transmitter would be of no service. The most important use of the automatic transmitters is for press news, but they are also used for ordinary messages on busy lines.

At the larger telegraph offices all the instruments are supplied with current from a storage battery, the number of cells for any one line depending upon its resistance. The longer the wire the greater the resistance, and therefore the more pressure required to send the current through. In order to decrease the resistance on long wires, they are made of better conducting properties.

When an electric current has travelled a long distance its strength is considerably reduced owing to the resistance of the wire, so that an electric impulse, on reaching a far-distant town, may not have sufficient energy left to cause the electro-magnet to attract the comparatively

heavy armature required to make a distinct sound or to cause a recording instrument to impress the signals clearly on paper. This apparent difficulty is very easily overcome, for as long as there is a very small current this will be sufficient to cause a small electro-magnet to attract a very light lever, and the movement of this lever can switch on a local battery to the telegraph instrument. This small electro-magnet and lever arrangement is called a "relay," or repeater, and when the operator depresses his key, or when he makes a series of up-and-down movements, the electro-magnet of the distant relay causes its lever to make a similar number of up-and-down movements, so that this lever exactly imitates the sending key and operates the telegraph instrument to which it is attached.

On going into the telegraph room of a large post office the stranger merely hears a meaningless rattle of clicks, but to the experienced telegraphist it is just as though he were in a crowded room and heard a number of conversations being carried on by different parties. The operators sit in rows at narrow tables or benches, to which their telegraph instruments are fixed. The wires pass along these tables, one wire leading from the battery room to the operator's contact key, and the other wire back along the table to a board whereon are fastened all the ends of the outside telegraph lines.

One does not find a great network of wires over a large telegraph office, because the wires are led through the city underground, and then they branch off in all directions, carried on the familiar telegraph poles. These overhead wires have often been a great source of trouble

during a severe storm of wind or snow, their downfall causing serious dislocation of commercial business, so that the Post Office has been forced to make some of the connections between the more important cities by insulated wires buried in pipes in the earth.

Even with overhead connections each wire means a considerable expense, and so telegraphists found means of sending more than one message at a time over a wire. It seems to the stranger quite ridiculous to attach several telegraph instruments to each end of a single wire; one would expect an utter confusion of signals, but it is not so. Every line of importance in this country is "duplexed" to carry two messages at one time, there being, of course, two operators at each end. One of these operators sends messages, while his local partner is receiving messages from the distance, and yet there is no confusion.

It would be difficult to give a clear statement of how this is done without going into technical details, so I shall merely remark in passing that one may picture the receiving instrument as being electrically shielded from the outgoing current leaving the same station, and only affected by the incoming current, so that a transmitting operator at each end is sending messages out to a receiving operator at the opposite end of the wire. At large centres eight operators use one wire at the same time, there being four operators at each end. Two operators are sending messages out, and the other two are receiving messages, and each receiver picks up its own message in this manner. A current is kept constantly flowing on the wire, neither receiver is affected by this current, but a

change in the strength of the current operates the one telegraph, while a change in direction of the current moves the second receiver.

Inventions have been made whereby a larger number of messages may be sent over a single wire simultaneously, but these are not in everyday use. In one system it is arranged to give each operator the use of the wire in turn; his turn recurring as quickly as he can possibly make use of it. This system requires a rapidly revolving connection at each end of the wire, both mechanisms keeping perfect time, and the mechanical difficulties of keeping these two motors in absolute harmony with each other has proved too much for ordinary practice.

Another inventor sends as many as a dozen messages at one time over a single wire, using telephone receivers, which each hum a different sound, each telephone replying to its own signals only. The sounds, of course, represent the clicks of the Morse alphabet.

Among other recent inventions is one in which a perforated tape is prepared to transmit currents to a distant receiver which contains a tiny mirror, throwing a spot of light on to a photographic paper. The movements of the mirror are so controlled by the current that the pencil of light traces out the different letters of the alphabet upon the paper. It reminds one of a boy reflecting the sun's rays against a wall by means of a small mirror. He can make the spot of light dance about at will, and, if the irresponsive wall would only retain the impression of the spot of light, the boy could write upon the wall with his pencil of light.

In the telegraph instrument one particular set of per-

forations passing through the transmitter causes the tiny mirror in the receiver, at the distant end, to move so that the letter A is traced upon the photographic paper; another set of perforations produces B; and so on. The photographic paper, after receiving these impressions, is chemically developed, and fixed by the receiving instrument. This instrument has the advantage of a very high speed in working, as many as 40,000 words having been telegraphed over a considerable distance in one hour, which means that the whole of the text of this book could be telegraphed in less time than one could read a quarter of its contents.

Another advantage is that the receiving instrument delivers the message to the operator in ordinary writing. For the reception of press news, this advantage is rather lost, as it is necessary for the Post Office in any case to write out a number of copies by means of a manifold book, sending one copy to each of the local newspaper offices. An expert will read the regular Morse signals about as easily as the ordinary A B C, so that the longhand written message is of no great advantage to him.

There seems to be a large field open for typewriting telegraphs. These have been used on the Continent for a long time, but one disadvantage has been that the message was written on a tape or ribbon of paper.

There is great activity in this line of invention at present. One inventor uses a typewriter to prepare a perforated tape, which is run through the transmitter, operating the distant receiver, which produces a similar perforated tape, which, in turn, is run through a special typewriter, producing the message in letter form. This

may seem a somewhat roundabout method, but the object is to gain a high rate of speed in transmission over the line. Other inventors are at work with type wheels in the receiving instruments to be controlled by a distant transmitter, having keys similar to a typewriting machine; the message to be in page form, ready for delivery. This is really equivalent to having the keys of a typewriter at one end of the line wire while the types are at the distant end. There seems little doubt we shall some day receive our telegrams in typewritten form, just as produced by the telegraph instrument.

There is an invention of long standing by which one may write in ordinary hand, using a pen connected to some electrical mechanism, and a pen in the distant receiver will exactly imitate every movement of the pen in the transmitter, so that one may write a letter or sketch a picture on the transmitter, and a reproduction will simultaneously appear at the distant receiver. This apparatus is most ingenious, and would, no doubt, have come into general use for private lines, but for the advent of the telephone.

The telegraph business has grown to an enormous extent. In Great Britain alone there were ninety-three millions of telegrams passed over the wires in the year 1903, while the United States of America followed closely with ninety-one millions; France and Germany each handling about half as many, while Russia and Japan despatched nineteen and seventeen millions respectively. But for the growth of the telephone system there is no doubt these totals would have been much greater by this time. However, taking the grand total of the six

countries above mentioned, one finds that these countries among them handle about one million telegrams every day of the year, omitting Sundays.

The total of telegrams handled by the British Post Office in 1904 was about three million less than in the previous year, and no doubt one of the main causes of this decline has been the rapid increase of telephonic communication.

While Great Britain leads in telegraphic messages, it comes far behind with its telephone total. In the United States over five thousand millions of telephone messages have been exchanged in one year, so that for every telegram despatched in America fifty telephone conversations took place. There is not the least probability of the telegraph being ultimately eclipsed by the telephone for long-distance work, but great changes will doubtless take place within the next generation, and it may be that the telegraph will become the usual means of transmitting ordinary business correspondence at a very low rate.

CHAPTER VIII

TELEGRAPHING ACROSS THE SEA

Early attempts to lay submarine cables—A bold proposal—The first Atlantic cable—A long chapter of accidents—Success and failure—The *Great Eastern's* task—A search for a lost cable—How the messages are signalled—A wondrously sensitive instrument—How cables become faulty—How faults are located—Early prices for cable messages—A cable behaves quite differently from a bare wire—A young man reads a prophecy in the fulfilment of which he is afterwards destined to take a prominent part.

IT is a comparatively easy thing to connect two places on land together by means of a wire stretched between poles right across the country, but to attempt to connect two places with a vast ocean between is a much more difficult task. In the early days of land telegraphy many experimenters tried to lay an insulated wire under water, but with varying and short-lived success. After one almost complete failure in attempting to connect Dover with Calais, which exploit was generally accounted a mad freak, it required a sanguine man to raise a sum of £15,000 to make a second trial. It is to the credit of Mr. T. R. Crampton, an eminent railway engineer, that he not only raised the sum in 1850, but that he subscribed half of the required amount out of his private purse. It was not without difficulty

that even this comparatively short cable was laid, but the success that attended it gave promise of greater achievements.

Further advance was not to be all plain sailing, for three different attempts to connect England and Ireland only ended in sinking expensive cables that were quite unable to withstand the strong tidal currents, etc. A fourth attempt with a much heavier cable fortunately proved successful.

It was soon boldly proposed that an attempt should be made to span the great Atlantic Ocean, and thus connect Europe with America. This was indeed a bold suggestion, for the laying of all previous cables was mere child's play when compared with the spanning of a great open ocean, measuring at places nearly three miles in depth. It is somewhat surprising that there was not much difficulty in raising a capital of £350,000 towards the laying of an Atlantic cable, which must needs have been pretty much of an experiment.

It is difficult even to conceive the magnitude of the task of manufacturing a cable over 2,500 miles in length, but some idea of the stupendous work may be obtained by a mere statement of the fact that this cable, which was made of several strands of copper wire for the conductor with a substantial insulation of gutta-percha and an outer protection of iron wires making, as it were, an iron rope with an insulated copper core, required a total length of wire more than sufficient to stretch from the earth to the moon. However, the manufacture and also the stowing away of the cable into the holds of one British and one American man-of-war were easy tasks as

compared with the difficulties in laying the cable safely on the bed of the great ocean.

Having left one end of the cable on the Irish coast the great American warship steamed slowly away, but before a paltry five miles of the cable had been paid overboard the cable caught in some of the paying-out apparatus and parted. The lost end was with difficulty found by tracing the cable from the shore end. After splicing this to the rest of the cable all went well for a few days, but once more the cable snapped, leaving some 380 miles at the bottom of the ocean, the broken end going to a depth of 2,000 fathoms. The ships had to return home and abandon the lost cable, but ultimately recovered fifty miles of the shore end.

In the following year (1858) the great ships steamed off once more with some 3,000 miles of precious cable, and with improved machinery for paying out. Previous to starting on this second voyage the steamers had made extensive experiments in laying some defective cable in the Bay of Biscay, in order to test the new machinery and give practice to those responsible for its control. On this occasion it was decided that both steamers should begin at the middle of the ocean, and after splicing the two cables together pay out in the directions of the two shores. This plan was proposed at the very outset by the engineer-in-chief, but was objected to by the electricians, who preferred that one steamer should lay half of the cable from the Irish shore to mid-ocean, where the other ship was to join up its cable and lay the second half to the American shore. However, it was decided to try the mid-ocean start this time, but before reaching

mid-ocean the British war vessel was almost lost in a storm, owing to the great dead weight she carried. Having met and spliced the cables, the two ships had not gone many miles paying out the cable when it broke, and another start had to be made.

During the laying of the cable electrical communication was kept up between the ships through the whole length of the cable, and after some forty miles had been paid out in this second attempt the electrician (late Lord Kelvin) reported to those on deck that another break had occurred, apparently at some distance from the steamer. Another meeting in mid-ocean, another splicing of the remaining cables, and the two vessels again made off for the distant shores, but after each steamer had laid over one hundred miles of cable yet another break occurred. At the last mid-ocean meeting it had been arranged that if a further break occurred before a hundred miles of cable had been paid out from the start the ships should once more meet, but if the cable snapped after they had passed one hundred miles they should each make for Queenstown. Those on board the British man-of-war decided to return to mid-ocean, as the break occurred only a few miles beyond the limit, but after hanging about the meeting-place for some days they found that the other vessel had evidently kept to the exact instructions, so that there was nothing for it but to return home too.

This was very disheartening, but it is most fortunate that, though the chairman of the Cable Company urged the abandonment of the whole scheme and the realising of what cable was left, it was ultimately decided that

another attempt should yet be made; and the vessels set off for the agreed dot upon their respective charts.

On this occasion, after many narrow escapes and much anxiety, the two ends of the cable were safely brought to the respective shores from the splice in mid-ocean, amidst much rejoicing on both sides of the Atlantic in the August of 1858.

After congratulatory messages had been despatched and reciprocated, the first piece of public news sent over the cable was information from New York of a collision between two of the Cunard mail steamers, compelling the outgoing vessel to put back to port. The message informed the friends in Europe that no lives were lost, and so spared them the anxiety that would otherwise have been caused by the non-arrival of the great steamer at her appointed time.

Among the early messages was one from the British Government to the generals of two British regiments stationed in Canada. Orders had been sent by mail that the regiments were to return at once to England and proceed to the East to help in suppressing the Indian Mutiny, but meantime the mutiny was quelled, so that there was no need of the assistance of these troops. The next mail would have been too late to cancel the orders, but by means of the new cable instructions were immediately sent, thus saving a sum of some fifty or sixty thousand pounds.

The troubles of the Cable Company were not all over yet, for very soon the long submarine conductor began to show signs of giving out. The messages became less and less distinct until they grew so faint that the signals were

confused, and ultimately died away altogether. During its short life the cable had carried between seven and eight hundred messages, but if a cable was only to last a short time it would not pay to lay one.

After much consultation and experimenting, it was determined that the cause of the failure was the use of too great intensity of current. Instead of merely using a battery as had been done in testing on board ship, the electricians had greatly intensified the current by means of large induction coils.

It was with difficulty that after a lapse of some years new capital was raised to make another attempt in 1865. Past experience helped in the manufacture of a better cable, both as regards strength and conductivity. It was on this occasion that the *Great Eastern*, which had proved a white elephant for trading purposes, having lain idle for the greater part of ten years, was employed to carry the whole of the new cable and to commence laying it from Britain to America. After several delays, owing to faulty parts in the cable, a break occurred which proved a serious trouble. Several attempts were made to recover the broken end, which was discovered and hooked three different times, but it was found impossible to get it raised, so that the *Great Eastern* had to return home with her task unaccomplished.

Nothing daunted, the company raised new funds, not only to lay another cable, but to attempt the completion of the lost one also. Both of these attempts proved successful in the following year.

It would seem almost ridiculous to attempt to find the end of a lost cable in the middle of a vast ocean, but as

particular note of the longitude and latitude of the place had been made at the time of the loss, the searchers were able to get somewhere near the lost treasure. With patience, the cable was at last found, but there were many sore disappointments before it was brought to the very surface, and even then it slipped away like a living sea-monster more than once, until the task began to seem quite hopeless. On one occasion there was much rejoicing when the end of the precious cable was apparently brought on deck, but one can imagine the feelings of the patient toilers when it was discovered that they had merely hooked a few odd miles of faulty cable which had been used in some experiments. After many failures, and just when about to give up in despair, the cable was at last brought on board from some shallower depth; and the sense of relief must have been great when the electrical tests proved it to be still in a working condition.

At the shore end those in charge must have almost given up all hope, but when in the quietness of a Sunday morning the watcher at the receiving instrument saw apparent signs of life, how eagerly would he decipher the signals and carefully note the message, which read:—"Ship to Shore; I have much pleasure in speaking to you through the 1865 cable. Just going to splice." Those who had secured the lost cable would feel justly proud when they succeeded in completing the whole length.

It was now clear that ocean telegraphy had come to stay. Many other cables were laid from place to place, and the cable companies of to-day do not hesitate to sink half a million pounds sterling in a single cable across the Atlantic, while a whole fleet of cable-repair-

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GROWTHS ON A SUBMARINE CABLE

This picture shows the appearance of a submarine cable after it has lain at the bottom of the ocean for a few years. It becomes encrusted with marine growths such as barnacles, star-fishes, sea-lilies, sea-anemones, and many other strange parasites of the deep.

ing vessels is constantly stationed in various parts of the world.

The telegraph apparatus, and even the delicate relay, as used on land wires, are much too heavy to be used on long submarine cables, so that it was found necessary to have a much more sensitive receiver, although for short cables (such as across the Irish Channel, etc.) ordinary morse-inkers are worked by the Post Office. It was by the inventive brain of Professor William Thomson (late Lord Kelvin) that a suitable instrument was devised. The principle upon which this works is very simple, and is in point of fact the same as already described in the needle telegraph. It will be remembered that the current passing in a coil of wire caused a magnetic needle to swing round. In this more delicate apparatus a very tiny magnet is suspended by a silk fibre, inside a small coil of very fine wire; but as a small movement of this little magnet could not be easily seen, there is attached to it a tiny mirror, which along with the magnet weighs only about a single grain. A lamp throws a fine ray of light through a slot in a screen, and this, falling upon the mirror, may be reflected upon the wall or upon a graduated scale. By this ingenious method a very small turning of the tiny magnet gives a large motion to the spot of light, as every boy who has annoyed his neighbours with a small sun-reflector will well understand.

At the present time there is a story going the round of daily papers and magazines to the effect that the use of a small mirror was suggested to Lord Kelvin by his eyeglass falling and dangling before him; but I think we may safely label this story "pure fiction" without referring

the matter to his lordship, for of all men Lord Kelvin would be well versed in every previous electrical device, and there is on record an early telegraph by two German experimenters in which they used a mirror to indicate the turning of a magnet, though it was a very clumsy affair. This fact does not detract from Lord Kelvin's invention, the beauty of which is its great sensitiveness, and the suggestion to use the reflected ray of light to point out the movement of the tiny magnet instead of attaching a pointer or indicator to the magnet and thus increasing its weight. This instrument is known as a "mirror galvanometer," and is used for making delicate tests.

The same great genius devised a means by which the movements of the little magnet might record the signals.

Fig. 7

The construction of this instrument, which is termed a siphon recorder, is somewhat different from the mirror galvanometer just described, but the principle is the very same. A very fine glass tube has one end dipping into a small well of ink and the other end close to a paper ribbon, which passes along by clockwork. This little tube acts as a siphon to carry the ink from the well to the paper, and it is operated by the little magnet, so that it is drawn to the right or left hand in sympathy with the movements of the magnet. In this way a record of the signals is taken, as shown in Fig. 7, in which the right and left movements are easily discerned on either side of the dotted line.

The alphabet is the same as in the simple needle tele-

graph, so that the letter A, which is indicated by the needle falling first to the left and then to the right, will appear on the cable paper as shown in the accompanying diagram.

It is interesting to note that in order to get the ink to flow freely through so fine a tube, the inventor found it necessary to electrify the ink. The idea no doubt was suggested by a discovery that was made in 1780, that water issuing from a nozzle in drops would flow in a stream if electrified. At a later date it was found that, if the siphon was given a vibratory motion, the same result was obtained.

Returning to the subject of the long submarine cables connecting distant lands, it will be quite evident that after a cable is safely laid at the bottom of the great deep it may not be in a very stable condition. If a cable were to be laid across the country from a balloon there would probably be many hilly places where the cable would not touch the ground, but would stretch from one hillside across a valley to another hill; and so it happens in similar fashion that there are many rough places at the bottom of the ocean where the cable stretches across a valley, and at such points it may easily become strained and ultimately broken by a rubbing friction caused by ocean currents, etc. Then, again, the cable may be slowly destroyed by chemical action in certain waters, or serious injury may be caused by submarine earthquakes, or, as has sometimes happened, a cable has suffered from attacks made upon it by some sea monster. On several occasions the teeth of such monsters have been found embedded in the cable coverings at places where faults

occurred, and at least twice has a great whale been found entangled with a cable.

It would be a very serious matter, when a fault occurs and signals become weak or altogether cease, if the repairing squad had to make an examination of the whole cable in order to locate the fault. Such a task would indeed be a thousand times worse than looking for a needle in a haystack, but fortunately for the success and the economy of cable companies, it is possible to find out in a very simple way exactly whereabouts the fault has occurred.

Every wire or cable offers a certain amount of resistance to the passage of an electric current according to the size and quality of the wire, and a particular note is kept of the exact amount of resistance a mile length of each cable offers. If a cable breaks at any point then the current gets to earth at that place, and by passing a current into the cable it can be seen by a galvanometer how much resistance is being offered to the current, for the smaller the resistance the more current will flow. Having found the total resistance to the current, it is easy to calculate the length of cable that offers such resistance, and if it be found to be equal to the resistance of 110½ miles of cable, then it is known that the break has occurred at that distance from the shore end, while the chart of the route will give the latitude and longitude of the particular place where the broken end must be lying.

In the Atlantic Ocean alone there are sunk some 40,000 miles of cables, giving constant employment to a very large staff of workers, clerks, etc.

Commencing with a charge of £20 for twenty words,

the price soon came down fifty per cent., and then to thirty shillings for ten words, at which figure it stood for a long time. In 1872 the price stood at four shillings per word, but thanks to increased business and competition we can now afford to cable very ordinary business or private messages at a rate of one shilling per word, and if the rate should drop to sixpence the public on both sides of the Atlantic will no doubt take a correspondingly increased advantage.

One great difficulty in telegraphing across the seas is that an insulated cable behaves quite differently from an ordinary bare telegraph wire. The cable becomes charged something like a Leyden jar, and thus retards the flow of the current, so that special condensers require to be used to assist the current.

The automatic transmitters described in the preceding chapter are also used on cables, but not so much for speed as to obtain a regularity of signals.

Lord Kelvin's connection with the pioneer cables is well known, but I have been very much interested to learn from Dr. David Murray that he remembers being present at a meeting of the British Association, held at Glasgow in 1840, at which a model of Ponton's Galvanic Telegraph was exhibited, the description of which closed with the sentence: "The further improvement of this instrument, and a more familiar acquaintance with its use, may ultimately lead to connections being made between the most distant countries in the world for the transmission of intelligence; and posterity may perhaps witness the receipt of news from India, by means of galvanic telegraph, in

as many minutes as there are weeks now occupied in the conveyance of a despatch."

It is remarkable that this apparently long look ahead was fulfilled for that generation, and that a young man, William Thomson, of Glasgow, who was present at that meeting, became the chief actor in this great historical event.

While the name of Sir William Thomson (afterwards Lord Kelvin) stands out very prominently in connection with the first Atlantic cables, it should be noted also that a great deal of the success in laying the cables was due to the ingenuity and skill of the late Sir Charles Tilston Bright, who designed and supervised the working of the paying-out machinery. As engineer-in-chief, Bright had many difficulties to contend with, and although only twenty-six years of age at that time, he overcame all these troubles which many of the leading men of the day said were insurmountable.

CHAPTER IX

SOME EARLY ATTEMPTS AT TELEGRAPHY

An ingenious surgeon in Scotland invents an electric telegraph 150 years ago—Other inventors—The great difficulty these early experimenters had to contend with—The beginnings of the practical telegraph—Thirty connecting wires reduced to one single wire—A very easily satisfied British Government.

ONE would not expect to find any attempt at telegraphy in the days when man's only knowledge of electricity was its wild and sudden discharge from an electrical machine, and yet there exist on record several very interesting attempts in those days prior to Volta's taming of electricity into a peacefully tractable current, as we have it from batteries.

It is evident that some attempts to transmit intelligence by electricity were made as far back as the middle of the sixteenth century, although the records of these are somewhat vague, and appear to have been carried out by some monks in a German monastery.

In the *Scots Magazine* of February 1st, 1753, there appeared a letter describing a practical electric telegraph worked by a primitive electrical machine. The letter was merely signed "C. M.," and was written from Renfrew, a small town on the River Clyde, a few miles below Glasgow.

The one property of electricity with which this ingenious writer would be most familiar was doubtless the attraction between an electrified body and any light object placed near it, and so it occurred to him that if he could charge a long connecting-wire between two places, then the distant end would attract a small piece of paper placed close to it. Having determined that this could be done, he set up twenty-six separate wires, connecting his dwelling to a distant cottage in the village. The wires were supported on insulators at short distances apart, being fixed at each of the two distant ends in a bar of solid glass, leaving about six inches of wire extending beyond the glass fixture. These six-inch ends were stiffened, so that if depressed they would spring back to their horizontal position. These free ends were then placed immediately above the glass cylinder of an electrical machine, so that while the machine was "excited" by rotating it, any of these twenty-six ends could be pressed down to touch the cylinder, and thus the whole length of this particular wire would receive a charge of electricity.

At a point close to where each wire entered the solid glass fixture the inventor suspended a short piece of wire with a metal ball at its extremity, there being, therefore, twenty-six separate balls. Immediately under each ball he placed a small piece of paper bearing one letter of the alphabet upon it. This arrangement was, of course, carried out at both ends of the line wire. To signal the letter A the operator, having set the electrical machine in motion, would take a piece of solid glass in his hand, and, depressing the end of the first wire till it touched

the cylinder, he would charge the whole of that wire so that the suspended metal ball at each end would attract its particular paper marked A. The person at the receiving end would take note of A, while the operator would see by the attraction of A at his own end that the wire had been sufficiently charged. In the same way all the twenty-six letters of the alphabet could be signalled in any desired order, thus enabling intelligible messages to be sent. The inventor says that the letters "were contrived to fall back into their proper places," so he may possibly have had a small glass division for each letter to rise and fall within.

The inventor also suggested, among other arrangements, that each of the little metal balls might by attraction be made to strike against a little gong, there being twenty-six gongs of different sounds, and the person using the apparatus would, as the inventor said, "soon understand the language of the bells." In this suggestion we have the first idea of a "sounder" telegraph, and it is by sound signals that most telegraph messages are now received.

The great difficulty in working any such apparatus as that just described would be to prevent the high tension charge from making a dash to earth through every possible means of escape, and in this connection it will be of interest to note a few sentences from the inventor's letter. He writes: "Some may perhaps think that although the electric fire has not been observed to diminish sensibly in its progress through any length of wire that has been tried hitherto; yet, as that has never exceeded thirty or forty yards, it may be readily supposed that in a far greater

length it would be remarkably diminished, and probably would be drained off in a few miles by the surrounding air. To prevent this objection, and save further argument, lay over the wires from one end to the other with a thin coating of jeweller's cement. This may be done for a trifle additional expense, and as it is an electric *per se*, will effectually secure any part of the fire from mixing with the atmosphere." Here we have, at this early date, the idea of an insulated wire as used for almost all electrical purposes at the present time.

It is interesting to note that the mental picture which this ingenious man formed of electricity was that of a "fire," which thought was very natural owing to the appearance of a spark at any point where the electricity suddenly escaped from one body to another.

The late Sir David Brewster made particular search to discover the history of this anonymous letter writer, "C. M.," and his efforts met with a certain amount of success. He first of all found out that a very clever man had lived in Paisley in 1791; that he came from Renfrew, which is only a few miles distant; and that it was reported of this genius that he "could light a house with coal reek (smoke), and make lightning speak and write." At a later date Sir David Brewster found that this man's name was Charles Morrison, who was a native of Greenock, but practised for some time as a surgeon in Renfrew, and ultimately became connected with the tobacco trade in Glasgow. Morrison was counted a wizard, and his neighbours believed him to be in concert with the devil, because of the apparently supernatural power he had of sending messages to a distant cottage.

He ultimately went out to Virginia, U.S., where he died.

Another early form of telegraph suggested was, that the sender and the receiver should each have a good clock, with the letters of the alphabet painted round the dial, and the two clocks keeping accurate time, the "second" hands would point to the same letter on each dial at the same moment. By a connecting wire between the distant places a Leyden jar was made to spark at the moment the hand was opposite the letter that the sender wished to telegraph, the receiver also noting the letter indicated on his clock at the moment when the spark occurred. The first idea of this inventor had been the very primitive method of striking, with some object in his hand, upon the bottom of a copper stew pan at the moment his clock was at the desired letter, but it is evident that this method of using sound could not have been extended to any great distance. His subsequent system of using the charged Leyden jar only required one wire, but the difficulty of keeping the charge to the wire would necessarily worry the inventor if he tried it over a distance.

A very similar and better known invention was Ronald's Electric Telegraph, in which the dials of the clocks moved round, bringing the letters of the alphabet painted upon them into view successively through an aperture in a covering case. When the desired letter appeared in the slot a signal was sent by discharging a wire at the end of which a pair of electrified pith balls, suspended by two threads, repelled each other until the discharge took place, whereupon they immediately came

together by gravity. By this primitive method the words of the message were slowly built up.

After Volta's introduction of batteries the idea of electric telegraphy became more practicable. While these two last-mentioned experiments were carried out with only one connecting wire, yet it was a long time before inventors could dismiss from their minds the idea that a reliable telegraph would require a great number of connecting wires. Even one of the greatest French scientists, Ampère, suggested an instrument which required as many as thirty connecting wires, and under the end of each there was to be placed a small magnetic needle.

A few years later a German professor proposed putting the thirty little magnets inside as many coils instead of merely under the single wires; by this means the effect of the current on the magnet was greater. An instrument of this kind was exhibited at the Royal Institution of London, in 1830, in which telegraph twenty-six wires, coils, and magnets were used. It was several years before anyone suggested that one wire with a single coil and magnet would serve the purposes of signalling.

To give even an abstract of all the early inventions in telegraphy would occupy a good deal of space, although every inventor who was bold enough to approach the Government of his day regarding his invention received the somewhat discouraging reply that "telegraphs of any kind other than those now in use are entirely unnecessary, as the Government are fully satisfied with the

semaphore system." How would the Government of to-day feel if instead of the electric telegraph they had to be satisfied with sending intelligence by means of optical semaphores, as used from one ship to another at close quarters?

CHAPTER X

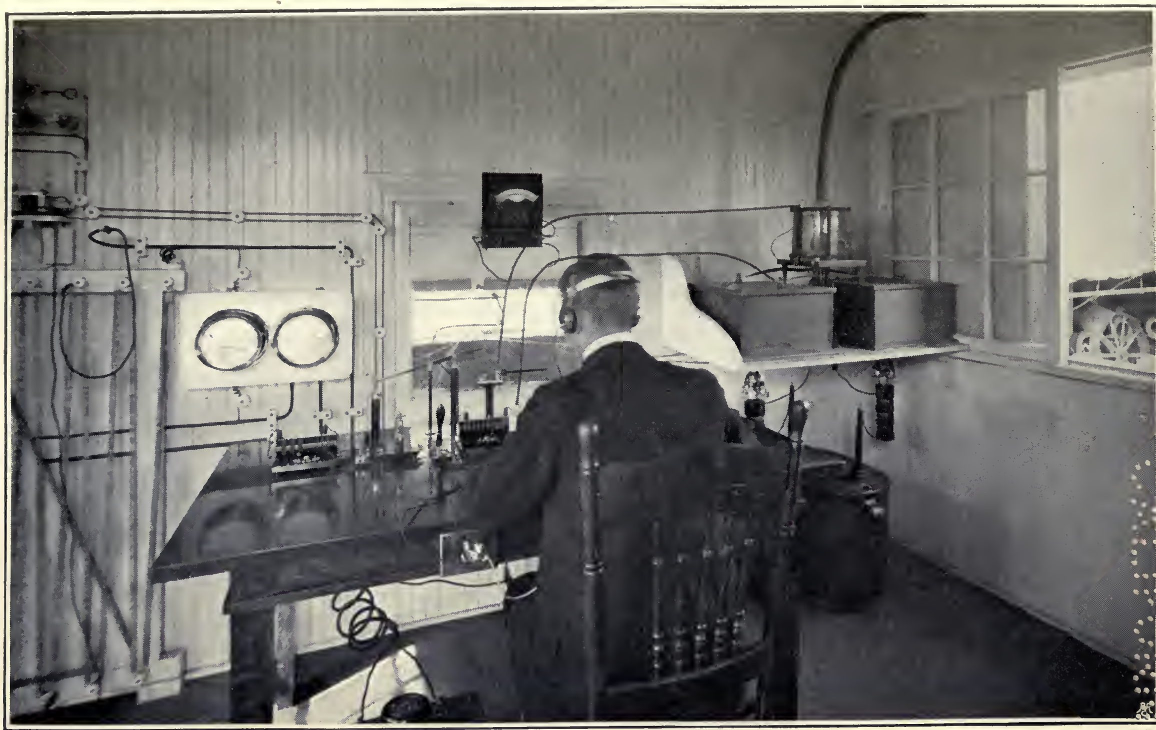
TELEGRAPHING THROUGH SPACE

An old-time swindler cornered by Galileo—Some interesting early experiments—Sir William Preece's method—How the present system is worked by Marconi and others—The importance of Wireless Telegraphy—Communicating with friends far out on the ocean—A "Wireless Press News" in America—The "tuning" of wireless instruments in order to obtain secrecy—Experience in the Russo-Japanese war—An exciting "wireless" incident—Noiseless wireless music.

THE idea of telegraphing to a distance without the aid of connecting wires is by no means a new one, although its practical accomplishment is within the memory of all.

Some three hundred years ago a man claimed to be able to send wireless messages over a distance of thousands of miles by means of two simple magnetic needles pivoted on dials around which the letters of the alphabet were written. No matter at what distance the two dials were placed from each other, the inventor stated that he had only to move the one magnetic needle to point at any desired letter, whereupon the distant needle would immediately turn in sympathy to the corresponding letter on its dial.

When the inventor was asked by the great Italian astronomer Galileo to show the instruments at work



By permission of *National Electric Signaling Co., U.S.A.*

A WIRELESS TELEGRAPH STATION

The operator is receiving a wireless message from a distance. He hears the clicks in the head telephone attached to his ears. and is busy typewriting the message as it arrives.

across his room, the adventurer said that when close together the magnets could not work; they required to be separated by a great distance before the one could influence the other. Galileo then suggested that the inventor should leave the one instrument with him, take the other to any distance he desired, and then send him a message, but needless to say this test was not convenient to the swindler.

Other equally absurd proposals were made, and no doubt believed in by some, but it naturally was not till after the practical electric telegraph was in use that any genuine attempt at wireless telegraphy was made. Of the early experimenters the most interesting is James Bowman Lindsay, of Dundee (Scotland), who read a paper before the British Association in 1859 on "Telegraphing without Wires." It is interesting to note that the illustrious Michael Faraday and our great scientist, William Thomson (Lord Kelvin), were both present at this meeting.

Lindsay was a great genius who lived for learning. He went to Dundee as science lecturer in the Watt Institution, and later he acted as tutor and conducted private classes. While acting for seventeen years as teacher in the Dundee prison on a salary of £50 per annum, he made many researches in electricity, constructing his own apparatus, and denying himself everything but the bare necessaries of life to enable him to follow out his studies.

In 1854 Lindsay took out a patent "for transmitting telegraph messages by means of electricity or magnetism through and across water without submerged wires, the water being made available as the connecting and conduct-

ing medium." By such means Lindsay sent telegraph messages across the Tay at a point where the river is about a mile in width.

More recently Sir William Preece worked out a method of wireless telegraphy on the principle that an electric current passing along one wire will, at each make and break of the current, set up a similar current in any other wire placed parallel to it, although the wires be placed miles apart from each other. The one drawback to this system is that the lengths of these two parallel wires have to be increased in proportion to the distance between them. Each wire must be about equal in length to the distance between the sending and receiving stations. It is apparent that on land one might as well connect the two stations directly by wire; but this system has proved of service on more than one occasion where submarine cables have broken down, as between the English coast and the Isle of Wight, and between the mainland of Scotland and the Island of Mull. If the distance from shore to shore be five miles, then a five-mile line is run along each coast.

The present method of wireless telegraphy, worked out by Signor Marconi, is more truly wireless, and is on quite a different principle.

What Cooke and Wheatstone did for the electric telegraph in Britain, and Morse in the United States, Marconi has done for wireless telegraphy. None of these inventors discovered the principles that made telegraphy possible, nor did they originate the ideas, but they brought known principles into practical form.

When each country nowadays knows exactly what is happening in the other countries of the world, it would

be surprising if the whole field of such an important matter as wireless telegraphy had been left to one worker; the following are some of the most prominent names in connection with wireless work: Marconi, De Forest, Fessenden, Lodge-Muirhead, Popoff, Jackson, Armstrong, Orling, Dolbear, Stone, Artom, Lepel, and Poulsen, &c.

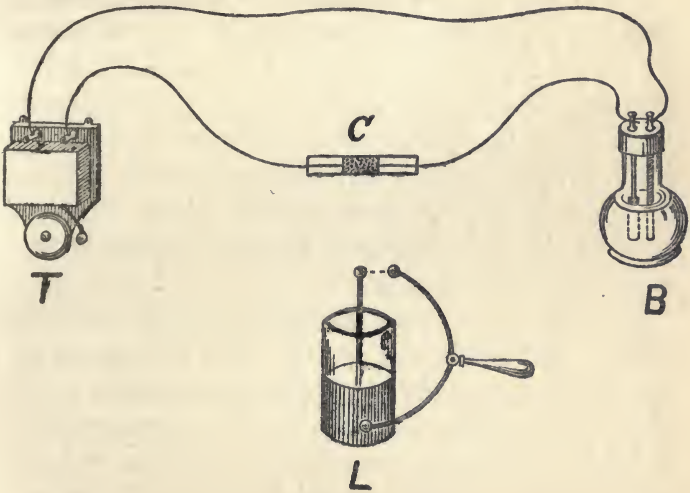


FIG. 8

THE PRINCIPLE OF WIRELESS TELEGRAPHY

The current from the battery (B) cannot get to the trembler bell (T) because of the resistance offered by the coherer (C). When an electrical discharge takes place from the Leyden jar (L), ether waves go out and affect the filings in the coherer, allowing the current to pass to the bell, thereby causing it to ring.

The general principle underlying all these systems may be easily understood.

In ordinary telegraphy the sender has beside him the battery and contact key, while the line wire conducts the

current to the distant telegraph instrument. It will be remembered that the contact key is merely a small lever which when depressed closes the circuit and allows the current to flow from the battery to the telegraph line. An ordinary bell-push would serve the purpose, though not so conveniently.

Let us now imagine the whole of the apparatus to be placed at the receiving station, so that the battery with its contact key and the telegraph instrument are all connected up close together at the one place. If the would-be sender at the distant station could now by any means influence the contact key at the receiving station, making it close and open the battery circuit at will, he would then be able to operate the telegraph instrument and convey intelligible messages.

It is, of course, quite impossible for the sender to operate the contact key which is now far beyond his reach, but it is possible to substitute something in the place of the contact key which can be influenced from a distance, even though the sender be hundreds of miles away from the telegraph apparatus he desires to control.

At the receiving station we now take away the ordinary contact key and replace it by a small tube or box of metal filings, so that the current will have to pass through the filings to get from the battery to the telegraph instrument. The filings are only very loosely packed together, and they offer so much resistance to the current that it cannot pass through them. This little tube, with the filings in their normal condition, is equivalent to the ordinary contact key when open. These filings are, along with every existing thing, immersed in the great ocean of

ether which pervades all space. We shall become more familiar with this all-pervading medium in a later chapter. For the present we shall be content to know that it is waves in this great medium which provide the connecting link between the transmitter and the distant receiver in wireless telegraphy.

It is a marvellous fact that if certain ether or electric waves fall upon these little metal filings, their electrical resistance to the current is so far diminished that the current is able to pass through them and operate the telegraph instrument. The tube is then shaken, the filings return once more to their ordinary condition, and no current can pass. It will be observed that in this action we have an equivalent of the ordinary telegraph contact key which may be closed and opened at will. It only remains to produce the necessary electric waves to operate it from a distance.

An ordinary electric spark produces waves in the surrounding ether, but a feeble spark can give only a small result. By means of what is known as an *induction coil* we can so increase the pressure of an electric current that it will leap across an air-gap, and in doing so it will produce a perfect torrent of sparks. Owing to this electrical discharge the surrounding ether is disturbed, and waves travel out in all directions. It is remarkable the distance at which these waves may be detected by the little tube of filings already described. In seeking to describe the function of these filings they were said to *cohere* together when the ether waves fell upon them, and from this description the tube became known as the *coherer*.

We may picture the operator at the sending station switching the current on and off from the induction coil, producing torrents of sparks at will. He knows that each time he does so ether waves will reach the distant receiver and cause the telegraph instrument to record the signal. If the sender wishes to signal the Morse code he will arrange the duration of his spark torrents accordingly. Three sharp torrents following close at each other's heels will record the Morse signal for the letter *s*. All the other signals which are detailed in Fig. 4, page 57, may be signalled in the same way.

As the coherer tube is a very small thing, it is connected by wires to metal arms or "capacities," which intercept the ether waves and conduct the electro-magnetic effect to the filings in the small tube.

It will be understood that the simple apparatus which I have described is descriptive merely of the general principle of wireless telegraphy. One can get very good results with such apparatus over a very short distance. For long distances we require a more powerful disturber of the ether and a more delicate detector at the distant receiving station. For distances up to about two hundred miles, a storage battery and an induction coil can produce sufficient disturbance in the ether. To send messages to greater distances necessitates the wireless station being equipped with an engine and dynamo for generating the necessary electric currents with which to set up the ether waves.

The receiver may be some form of delicate coherer or anti-coherer. This latter term signifies that the receiver does not require to be tapped or shaken after each

impulse. Another form of detector is based upon electro-chemical changes which take place in the receiver when the ether waves arrive. Those in this class are called *electrolytic detectors*, while they might be described also as anti-coherers. One such device is composed of a small tube similarly arranged to the ordinary filings tube, but with two little blocks or rods of tin, between which there is placed a semi-liquid paste, sometimes composed of alcohol with tin filings and lead oxide. The operation of this tube is exactly the reverse of that of the metal filings tube. It will be remembered that when the ether waves arrived they enabled the filings to close the local battery circuit. In the electrolytic detector the arrival of the ether waves stops a current which is kept flowing through the detector. The chemical paste in its normal condition permits the battery current to get across from the one tin block to the other, but the stimulation of the ether waves produces a chemical action which immediately breaks down this bridge and stops the current. Upon the withdrawal of the ether waves the paste returns at once to its normal condition and allows the battery current to pass again. The signals are therefore a sudden breaking and making of the battery circuit. How can these signals be read?

If a telephone receiver is connected to the tube and battery, it will be very easy to tell when the battery circuit is broken; there will be quite a loud click heard in the telephone. Any person using the ordinary telephone may hear a similar click by depressing the telephone hook, or support, while the receiver is held to the ear. Each time the support is depressed the

battery current is cut off from the telephone, and it is the stopping of the current causing a sudden change in the magnetic field of the receiver which produces the click. This makes quite a good demonstration of how the wireless messages are read.

Then there are *magnetic detectors*, in which we depend upon the incoming ether waves affecting a piece of magnetised soft iron. The general principle of these will be understood if we picture an endless band of soft iron wire kept in motion so that bit by bit the wire passes close to the poles of a permanent magnet. The magnetism of the wire tends to change as it passes from the influence of one pole to the other. It was discovered that the time required for this change was very greatly reduced when ether or electric waves fell upon the soft iron band. The magnetic change is thus rendered so sudden that it is capable of inducing a momentary electric current in a coil of wire through which it passes. This induced current is detected by a telephone receiver which is included in the circuit. The signals of the Morse code may be read easily by such means. The operator in the photograph facing page 94 is reading wireless signals by means of the telephone receiver, which is attached to his head so that he may have the free use of his hands.

There are many other interesting devices for detecting the arrival of the ether waves, but sufficient detail has been given to enable the reader to understand the general principles.

At all wireless stations there is some metallic arrangement extending up into the air to entrap the ether waves.

Such arrangements are called antennæ. Those of us who spent some of our boyhood leisure hours in collecting beetles and other insects will find this word a familiar one. It is the name of those little horns or feelers extending from the head of the insect. With this picture in one's mind one can see the appropriateness of the word as used in wireless telegraphy.

One method is to erect a simple wire on a pole. In another a whole network of wires is supported from strong steel towers built to a height of over two hundred feet. Sometimes the wires have been arranged like a great inverted pyramid, while one system employs a huge sheet-iron tube, not unlike a factory chimney, reaching a height of over four hundred feet.

Some of the most recent transmitters do not disturb the ether by means of torrents of sparks. They employ a very rapid to-and-fro or alternating current to set up the necessary ether waves. This method has been found much more economical in the power required for a given range of communication, besides having other advantages.

In the first days of wireless telegraphy we used to employ the picture of two men shouting to each other across a distance as being analogous to two wireless-telegraph instruments, while two persons using an ordinary air telephone or speaking-tube represented two ordinary telegraph instruments connected by a wire. The simple analogy of two men shouting always suggested the possibility of some third party being within range to hear the communication. Then again one knows the difficulties arising from a number of people all shouting

at the one time. Similar difficulties were bound to present themselves to the wireless telegraphists when they began to multiply the number of their installations.

From the outset we heard a good deal about the interference and interception of messages. One ship would even pick up a message sent out by some rival system of wireless telegraphy. This formed the most serious problem that the wireless telegraphist had to face. That very considerable success in overcoming this difficulty has been made is demonstrated by the following facts. One of our battleships was communicating by wireless telegraph to another ship-of-war distant from it about five hundred miles. While this signalling was in progress another wireless instrument on board the same battleship was receiving messages from a third vessel within close range. How can this be done?

The instruments are "tuned" so that they respond to each other. There is an experiment with tuning-forks which gives us a suitable analogy. The air-waves (sound) from one tuning-fork will cause a second fork of the same pitch to vibrate also. Unless the two forks are "tuned" to the same pitch, the one will not respond to the other.

We need not trouble with the details of electrical tuning, except to point out that the transmitter has to be arranged to send out a definite rate of ether waves, while the receiver is arranged to respond to that same rate of vibration.

In these days when wireless telegraphy has an established position, it is hardly necessary to point out its great value. We may debate the probability of wireless competing with ordinary telegraphy on land, or whether

it will ever enter into serious competition with ocean cables. We cannot, however, fail to see the very wide field which wireless telegraphy has entirely to itself. It has no rivals in communicating with ships far out at sea. It is impossible to overestimate the value of this. In addition to the communication of ordinary intelligence, there is the possibility of a ship in distress being able to call for help from those who cannot see her. It is difficult to realise what it would be to find ourselves drifting helplessly out of the track of steamers, where it would be impossible to attract attention to our disabled ship. Or picture the crew upon a sinking steamer, unable to call for any assistance. We have had some very remarkable instances of large vessels sinking, and the wireless operator succeeding in calling the help of other steamers to which it would have been impossible to signal by any other known means. Indeed, one has only to read the daily papers to be impressed with the great importance of being able to signal through space without the necessity of connecting wires.

That wireless telegraphy is likely to prove of value in warfare is appreciated thoroughly by both military and naval authorities. The old proverb that to be forewarned is to be forearmed still holds good; it is obvious that the earlier we can learn the whereabouts of the enemy the more chance we have of dealing with them to advantage.

CHAPTER XI

ELECTRICITY IN NATURE

Franklin handles the lightning—A Russian professor accidentally electrocuted at St. Petersburg—Different kinds of lightning—A false notion—Thunder rain-drops explained—How we may imitate the Swiss mountain air in our hospitals—The aurora borealis and magnetic storms—Wonderful electric fish—Earthquakes and volcanoes.

FROM the earliest ages man has been familiar with the lightnings and thunders of the heavens, but if anyone had dared to predict that these grand phenomena would be found to be due to the same source as that exhibited by rubbed amber, such a prophecy would have been deemed beyond all reason.

Although primitive electrical machines were constructed about the middle of the seventeenth century, it was some fifty years later before experimenters suggested that lightning was simply an immense electric spark; and it was not till some forty years after these suggestions were made that Benjamin Franklin, one of America's greatest men, was able to prove this to be a fact by drawing electricity from a passing thunder-cloud, by means of a conductor carried upwards by a kite, to make communication with the cloud. Using a metal key at the lower extremity of the wetted string, which acted as the conductor from the upper atmosphere, Franklin was able to

By permission of] [Mr. Taylor, Curator of Paisley Museum.

A vivid Flash of Fork Lightning taken over House-tops. The lightning discharge is exactly similar to the spark from an electrical machine, but on an immensely grander scale. The electricity is passing between a cloud and the earth.

perform all the known electrical experiments by charging bodies from this key.

Franklin had made known his intention of carrying out such experiments, and news of these particulars having reached France, the experiments were there successfully carried out prior to Franklin's demonstration in America.

When Franklin had succeeded in drawing an electric charge from a thunder-cloud, it occurred to him that it would be possible to rob these clouds of their charges and thus prevent them discharging to earth through high towers, etc., which were so often seriously damaged when "struck by lightning." In this way we came to have lightning conductors attached to high buildings.

It is amusing to read that at that time (the summer of 1756) a German scientist prevailed upon a clergyman to have a lightning conductor erected at his house, but it so happened that this summer was a very dry one, and the peasants, believing that this lightning conductor was the cause of their trouble, made so much noise about the matter that the reverend gentleman had to remove it.

The danger incurred by any person receiving a violent shock from a conductor drawing electricity from the clouds was not appreciated, and a Russian professor at St. Petersburg, having erected an insulated iron rod leading into his house with the object of studying atmospheric electricity thus collected, received during a thunderstorm such a shock that he was killed instantaneously. This victim to scientific research, Professor Richmann, had omitted to provide any connection whereby the electricity might have passed harmlessly to earth.

We now know that lightning is merely a sudden discharge of electricity from one cloud to another, or from a cloud to the earth, in every way similar to the discharge between the inner and outer coatings of a Leyden jar, but on an immensely grand scale. The noise of this great discharge becomes a mighty roar as it echoes through the clouds.

The quantity of electricity in a lightning flash is extremely small, but it is at a tremendous pressure. Here we have electricity leaping a great distance from a cloud to the earth, across the intervening air space measuring sometimes a mile in distance, and yet we should require a battery of one thousand cells or more to make the current jump over an interval of one-thousandth of an inch of air space.

Lightning without thunder is sometimes merely the reflection of a far-distant thunderstorm, or at other times it may be a quiet discharge from one cloud to another, where the difference of potential is not very great.

If the thunder quickly follows the lightning, we know that the discharge is taking place very close at hand. I can remember, when a youngster, being so close to a lightning discharge that the flash and noise seemed simultaneous. I felt a sudden contraction of the muscles, and I could plainly smell the ozone or electrified oxygen. On this occasion a building within a stone's-throw was struck by the lightning.

It is possible to roughly calculate the distance one is from a thunderstorm by timing the interval between seeing the flash and hearing its thunder. The light is seen practically at the moment of discharge, for light waves

in the ether would travel eight times round and round the earth in one second, but the sound, or air vibrations, will only travel at about 1,100 feet per second, so if the number of seconds between the lightning and thunder are noted, a simple calculation will give the distance the sound has had to travel. If fifteen seconds elapse, then the distance will be a little over three miles.

We can recognise three different kinds of lightning—fork lightning, sheet lightning, and ball lightning. In fork lightning we have a greater disruption than in sheet lightning, the latter appears as a slower discharge, although the whole time in which any electrical discharge takes place is a very small fraction of a second. Ball lightning is rare, and has the appearance of balls of fire bursting in the air with a loud explosion.

It is very amusing sometimes to read in the daily press the graphic account of a building struck by lightning. I recollect one report reading like this: "The lightning entered the building by the chimney, rushed across the floor, and making its way to the lower part of the house by the gas-pipes, it forced a passage through a crevice," and so on; and yet all this took place within one tiny fraction of a second. The disruptive effects of a lightning discharge into the earth have sometimes been so great as to give rise to the belief that a material thunderbolt had been shot into the earth.

If we force a very fine jet of water up into the air so that it falls in such fine drops as to be little more than a mist, and if while this is happening we electrify a vulcanite rod, by simply rubbing it with a cat's skin, and bring this small electrical charge near to the fine stream of

water particles, they become electrified, and uniting together they form quite large drops. This experiment is a very good representation of the heavy rain accompanying a thunderstorm.

One often feels a decided heaviness or want of life in the atmosphere immediately before a thunderstorm, but as soon as the storm is over the oxygen of the air seems to have gained renewed vigour.

It is well known to all that great benefit is derived from the high mountain air of Switzerland by patients whose breathing apparatus is defective. On these mountain-tops we find a large quantity of ozone or electrified oxygen, and in addition the air is free from a good deal of both the organic and inorganic matter to be found in the vicinity of cities, while the air being dry and cold, its dust particles are easily repelled from the heated surfaces of the lungs (see p. 137). Some twelve years ago I made the suggestion, through a medical friend, to the staff of one of our hospitals, that in a ward with patients suffering from diseased or weak lungs an apparatus might be arranged to alter very considerably the conditions of the air, and bring these nearer to those existing on the Swiss and other mountain-tops. I proposed that the air should first of all be cleaned by filtering it through glass-wool, etc., that it should be dried and then cooled to a convenient temperature, while some additional oxygen might be added if desired, and then finally passed through a large vulcanite chamber, in which some high-frequency machines would be kept discharging, for the production of ozone, and the air in this altered condition might be

led into the ward through vulcanite tubes and distributed at the patients' bedsides.

The suggestion met with some approval, and I was offered facilities to carry out experiments, but not being connected either with the electrical industry or with medical practice I merely offered the suggestion that those specially interested might make the experiment, the result of which seemed to me a foregone conclusion. Nothing was done, but I have been interested to note of late that the same idea has been carried out in other quarters.

In contrast with the terrorising lightning we have the beautifully peaceful display of the aurora borealis. While this exquisite phenomenon is not of very frequent occurrence in our latitude, it may be seen nightly in the polar regions, but never at the equator. This beautifully luminous effect occurs in the heavens at both poles of the earth, but that at the south pole is termed aurora australis. Franklin explained these phenomena as due to discharges of electricity through rarefied air, such as we see on a small scale inside a vacuum tube. The magnetism of the earth is disturbed in the neighbourhood of these displays, and we have what are termed magnetic storms. In a telephone having an "earth return" instead of a complete metallic circuit, strange sounds may often be heard in the stillness of the night, due to earth currents possibly set up through the medium of the ether by some disturbances in the sun. The whole telegraphic circuits of this country are occasionally completely upset by these magnetic storms.

Electrical phenomena have long been known to exist

in the animal world—indeed, one of the earliest electrical observations was that of certain fish being able to deal out startling shocks. This fact is recorded by the greatest of ancient philosophers, Aristotle, more than three hundred years before the Christian era. We also have some interesting details noted by Pliny, who lived early in the first century of the Christian era and who lost his life by suffocation from the fumes of the great eruption of Mount Vesuvius, on landing to witness the great phenomenon. Pliny records the fact that when the torpedo, an electric fish found in the Mediterranean, was touched with a spear, "it paralyses the muscles and arrests the feet, however swift." Then we have the ancient record, mentioned later in chapter xxiii., of a man having been cured of gout by the shock from one of these torpedo fish.

Although these properties were known for such a very long time it was not till late in the seventeenth century that modern naturalists gave the matter any serious attention. It was only then that this shock was recognised as being of electrical origin.

Our present knowledge includes some fifty different kinds of fishes which show electrical properties, but the best known are the Electric Eel (*Gymnotus*) and the Electric Ray (*Torpedo Galvani*). The Gymnotus, which measures five or six feet in length, is said to be able to deal out a shock sufficient to kill a man.

Many experiments have been successfully performed with the electricity derived from these fish, such as the lighting of an incandescent lamp, the magnetising of needles, and the decomposition of water.

This electrical property has doubtless been bestowed upon the fishes as a means of preying upon smaller fish for food, and probably also as an active means of self-defence against greater monsters. There still remains a great deal of uncertainty as to the nature of the production of these shocks.

With the advent of delicate electrical tests it was found that in our own bodies there are continual electrical changes taking place on a small scale.

Earthquakes, although experienced from ancient times, have received little scientific attention until quite recently, and even now little is really known as to their origin. One great astronomer has asked us to imagine the solid crust of the earth to be no thicker in comparison with its molten contents than an egg-shell is to its yolk. We are then to suppose an earthquake to be due to the cooling down and consequent shrinkage of the molten centre and the necessary taking in of the outer coating to adjust itself to the new condition, as an older brother's suit or clothes might be cut down to fit a younger brother. Other physicists argue that the earth is solid throughout, and that there is no fusion, although the internal temperature is enormous. The reason why it may be at a very high temperature and yet not fuse or melt, is that the materials are under a great pressure, and if a body is subjected to a great increase in pressure it requires a very much higher temperature to fuse it. This view suggests that the molten effusions from volcanoes are merely local and do not necessarily prove that the earth's centre is molten. If a body that would melt on the

earth's surface at, say, one thousand degrees be subjected, in the bowels of the earth, to such a pressure that, although it is there at a temperature of two thousand degrees, it does not melt, and if the pressure be suddenly removed or relieved by some disturbance elsewhere, the heat it contains will instantly liquefy it. Whatever may be the true causes, for there will certainly not be only one cause operating, the great material disturbance is bound to give rise to an alteration in electrical conditions in the earth; but my present purpose in referring to the subject of earthquakes here is in connection with the recording of such disturbances by electrical apparatus as will be described in a later chapter.

CHAPTER XII

INTERESTING APPLICATIONS OF ELECTRICITY

What makes the electric bell ring—How indicators work—An alarm-clock that will insist on its victim rising—Automatic fire-alarms—A room automatically kept at an even temperature—A burglar that knew too much, and yet not enough—The block system on railways.

IN addition to the principal applications of electricity separately dealt with in the various chapters, there are manifold other uses in everyday life to which this willing servant may be put. Perhaps the commonest is the electric bell, which alone covers a wide field. Its principle is very simple and its operation interesting, and yet how many possessors of these bells have ever taken the trouble to lift off the outer case to see how the bell works.

Under normal conditions the electricity cannot get from the battery to the bell, because the connecting wire is purposely broken at the "push" on the wall, but when anyone presses the button of the push, the two ends of the wire are pressed together, and the current gets through, and rings the bell.

The current passes round an electro-magnet, causing it to attract a lever towards it, and on the end of this lever is a gong-stick, which thus coming quickly forward strikes

the bell or gong. This will, of course, only make one stroke each time you send the current through by pressing the button, so bells of this kind are called single-stroke bells, and are used for signalling on tramway cars and for many other purposes; but when you wish to call the attention of a servant you prefer to have something a little more vigorous in its action.

With the single-stroke bell you could easily make a series of blows upon the gong by repeatedly pressing and releasing the push alternately, but this proceeding would be rather tiresome, so the bell is arranged to do this making and breaking of the circuit for you. Instead of leading the current directly to the electro-magnet, the wire is attached to a little pillar, against which the gong-stick leans when at rest, and the current must pass up this pillar, and thence through the gong-stick to the wire of the electro-magnet. As soon as the push is pressed the current gets through from the pillar to the magnet, which immediately attracts the gong-stick forward against the gong, but as the gong-stick is no longer touching the pillar, through which the current was getting over to the magnet, the magnetism ceases, and the gong-stick, being no longer attracted, falls back again against the pillar, whereupon the current once more gets across to the magnet; the gong-stick makes another stroke, falls back again, and so on, continuing to tremble between the pillar and the magnet as long as the button of the push is held in. These bells are the ones in common use, and are called "trembler bells."

The ordinary push consists merely of two pieces of brass spring mounted in a wooden or metal case. The

wire from the battery to the bell is cut at the place where the push is to be fixed, and the two wire ends are fastened to the two brass pieces, which are normally standing clear of each other, but which are pushed together by the little "ivory" button, completing the circuit, which is again broken when the button is released.

Before electric bells came into use it was customary to fit up, in the servants' quarters in a house, quite an array of swinging bells, each of which had a different tone, and the maids were supposed to know which room was indicated by the particular sound of the bell. We all have some experience of the inadequacy of such a system through the failure of a servant to understand the language of the bells. It is possible now, with the aid of an electrical indicator or annunciator, to use only one bell for several hundreds of rooms in a large hotel. The wire from each push passes round a separate little electro-magnet, and then to the one bell, so that the current will magnetise this special electro-magnet as well as ring the bell. This small magnet may be made to attract a little lever, and allow the flap or shutter of an indicator to fall, leaving the number of the room exposed, or it may be made to set a small pendulum swinging, on the bob of which is carried a brightly coloured disc, placed immediately over its particular number, and so on. It may also be arranged that the bell continues to ring until the attendant stops it.

These continuous-ringing bells are now used for many purposes, and are such that when the gong-stick moves forward under the first impulse, a small spring which was resting on the gong-stick falls down against a contact

piece and closes the circuit from the battery direct to the bell, so that when the bell has once been set in motion from the distant push, it will continue ringing until this little spring is lifted off the contact piece and again held up by the gong-stick. The value of such an arrangement will be appreciated in connection with a fire-alarm, as it commands attention.

Anyone requiring to rise early in the mornings, and finding the ordinary alarm-clock insufficient, may remove the gong from the clock, and cause the little gong-stick to set in motion one of these continuous-ringing bells, which will certainly give him no peace till the unwilling victim rises and replaces the contact spring.

Many years ago, and before the introduction of these continuous-ringing bells, I made up a reliable alarm in the following fashion. Fixing an ordinary trembler bell on the outside of a battery box, I placed a brass hinge on the top of the box, screwing down the one-half of the hinge and leaving the other free to be lifted or let down on the box lid at pleasure. Underneath this movable end of the hinge I placed a little metal plate or contact piece, fixing one wire from the battery to this, so that the current could only get to the hinge when it was in contact, and thence by a wire attached to the fixed half of hinge to the bell. Having removed the gong from an ordinary cheap alarm-clock, I placed on the top of the clock, and lying against the gong-stick, a round piece of metal which was attached by a string to the free end of the hinge, normally standing up away from the contact piece. When the alarm of the clock goes off the gong-stick kicks the metal piece off the top of the clock, and in

falling it pulls the desk-hinge down on to the contact piece completing the circuit, setting the electric bell in operation, so that the would-be sleeper must bestir himself to rise and lift the hinge off the little metal plate. The apparatus is very simple, and I used such an alarm for many years, without finding it to fail me once, and having given several young engineers duplicates of it, I have received from them the same report.

I remember one young engineer who arranged his alarm-clock so that as soon as it commenced to ring it also began to walk along the mantelshelf, so that he had to make haste and check its suicidal intentions. Another young man who desired to have as long in bed as possible arranged his clock to make a preliminary and somewhat feeble alarm, but at the same time to turn on the gas-light under a small kettle arrangement, and when the water boiled the enclosed steam blew a whistle placed on the tightly fitting lid, thus informing its master that everything was now in readiness.

We now have automatic fire-alarms, whereby the excessive heat of any place catching fire will close an electric circuit and give the alarm direct to the fire brigade. A simple arrangement by which heat may be made to close a circuit is a piece of curved spring, made up of two flat pieces of different metals, which expand at different rates, and being clamped to each other at both ends, the curved spring uncurls till it comes against a metal contact, thus completing an electric circuit, just as one does in pressing the button of a bell push. There are many other devices, but this one will serve as an illustration of how an alarm of fire may be automatically given.

This device, which is called a thermostat, may be arranged to give an alarm if the temperature of a greenhouse rises too high or falls too low, by placing the free end of the metal curve between two contact pieces, so that if it either curls or uncurls a certain amount it will come in contact with one or other of these metal stops and complete the circuit. I have seen the temperature of a room automatically kept constant by such an arrangement. Gas-stoves were placed here and there around the room, and each stove was under control of a thermostat, as just described. When the temperature began to rise, the thermostat, instead of causing a bell to ring, operated an electro-magnetic device which lowered the gas, or if the temperature rose sufficiently, turned the gas off altogether, leaving only a small pilot jet burning, similar to the by-pass of an incandescent gas burner. When the temperature came down again, the metallic curve leaving the contact piece allowed the electro-magnetic device to turn the gas on again. The room was kept, by this means, always at a constant temperature, never being more than half a degree above or below the desired heat.

When electric heating can be obtained at a marketable price, I have no doubt that it will be a common practice to have the temperature of our houses and offices automatically controlled. What a boon it will be to the household to dispense with troublesome fireplaces.

If it is desired to know exactly when some liquid reaches a definite temperature, it is an easy matter to make up an ordinary mercury thermometer for the purpose. The wire from the battery is passed through the glass bulb, so that it is in contact with the mercury, while

another wire enters the long stem at the place where the specified temperature is marked off, so that as soon as the mercury rises to this point the current will find a passage through the mercury from the wire in the bulb, up the stem, to the other wire, and thence to the alarm-bell.

Electricity is called in as a detective to prevent burglars entering a house unnoticed. The opening of a window or a door completes a circuit and a bell rings in the master's room.

In America, where burglar-alarms are more common than in this country, houses are sometimes connected up to the nearest police-station, so that an alarm may be given if the house is tampered with while it is unoccupied. I remember hearing of a burglar who detected one of these wires which led to the police-station, and correctly guessing what it was, the burglar took the precaution to cut the line of communication between the window and the police-office before attempting to force an entrance. No doubt he would congratulate himself upon his foresight, and possibly he may have been a little more deliberate about his work than he would otherwise have been, for while he was still busy opening the window he found himself in the clutches of the law. The secret of the surprise was that the wire leading away to the local police-office was carrying a very weak current, which kept a magnetic needle, at the police-office, deflected to one side. If a window or door was opened the wire was broken thereby, and with the stoppage of the current the little magnet at the police-station was no longer deflected, and on reaching its normal position it made a contact and set an alarm-bell going, so in the above case the burglar

sent the alarm by cutting the wire before he attempted to open the window.

The application of these burglar-alarms has been so developed that the intruder may be photographed while tampering with a safe. A very clever capture was made some years ago in America by an electrical alarm which set off a flash-light and pulled the trigger of a camera, directed to take a view of the front of the safe. In this way the burglar was unconsciously photographed, and was easily recognised by the police authorities.

There is an almost endless variety of uses to which electricity may be adapted for giving alarms and signals of one kind or another, but the one particular application which stands out pre-eminently is that of signalling between railway signal-cabins. Our present complicated railway traffic would be quite impossible but for the aid of electricity.

Doubtless everyone knows something of the "block system" of railway working, but as there often seems to be an unnecessary mystery as to what this really means, it will be well to explain the principle. The railway is divided into sections or "blocks," there being a signal-cabin at the entrance and the exit of each block, so that one signal-cabin controls the exit from one block and the entrance to the next.

To take the simplest case of a cabin which is merely a passing-place, and not a junction, and having only one up and one down track to control.

In addition to his ordinary telegraph instruments and signalling bells, by which the signalman can communicate with the cabin on either side of him, he has a special

needle instrument for indicating whether there is a train in his section or not. It will be remembered that in a needle telegraph the little magnet, being pivoted at its centre, remains vertical or upright when at rest, but if a current is sent through the coil in one direction the magnet will be deflected to the right, while a current sent in at the opposite end of coil will deflect the needle to the left, so that the needle has three distinct positions—upright, slanting to the right, and slanting to the left—any of which it may be made to take up at will and remain there as long as the current is left on. The dial of the indicating telegraph is marked off so that when the needle is standing upright it points to the words "line blocked," which signifies that the semaphore signals are set at danger, but that there is no train on the section between the cabins. When the needle is deflected to the right it points to the words "line clear," which informs the signalman that the section has been prepared to receive a train, the outdoor semaphore signals having been lowered. Slanting to the left the needle points to the words "train on line," meaning that a train is actually passing between the cabins. This special telegraph instrument we will call the "block" instrument.

The working of these signals may be simply illustrated by supposing that we are in the central cabin, No. 2, having No. 1 to our right and No. 3 to our left. A train is on its way from No. 1 to No. 2, so No. 2 telegraphs to No. 3 asking him, in code, if his line is clear; this he does on his ordinary telegraph apparatus. If the train may proceed, No. 3 answers, in code, that the line is clear, and he also puts his block instrument to "line clear,"

which at the same time makes No. 2's block instrument point to the same words. The needles remain in this position, so that No. 3 cannot forget that he has given permission for a train to come on, and No. 2, looking at his indicator, has confidence in sending on the train, and he can, therefore, set his outdoor signals to the "clear" position, the semaphore signal being analogous to a policeman who holds out his arm to stop the traffic, and drops it to his side to let the driver know he may pass. The engine-driver must not dare to go past the policeman-signal when the arm is up.

When the train is entering No. 3 section from No. 2, the latter signalman must telegraph to No. 3, saying, "train entering section," and No. 3 must acknowledge it, and change the block instrument in his own and No. 2's cabin to "train on line," where it will remain as a constant reminder to both men that there is a train in their section.

When the train has passed No. 3 and gone into the fourth section, No. 3 advises No. 2 by telegraph, "train out of section," and also moves their block instruments to "line blocked." There are many varieties of block-signalling instruments, but the one just described will serve to illustrate the principle.

I have often found people giving an entirely wrong meaning to the block system, believing that it is impossible for a signalman to allow a train to pass when the line is not clear, because of some connection between the outdoor signals, or the train itself, and the telegraph apparatus, but in the ordinary block system in general use there is no such connection. The conditions of

working are just such as have been briefly indicated here, in which the block telegraph may be regarded merely as a safeguard in making the instructions from one signal-cabin to the next quite clear and "permanent" till the duties have been performed, but it is a possibility for the man at No. 3 to signal "train out of section" to No. 2 before the train has really passed, and in the same way it is possible, though, fortunately, not very probable, that No. 2 may send on a train without getting permission to do so.

The block system does not relieve the signalman of his responsibilities and reduce him to a mere automaton, as some people are inclined to think, but its great advantage is that the needle keeps pointing to the instructions until they have been made use of.

There is a method, called the "lock and block system," in which the outdoor mechanical signals are really connected to the circuit controlling the block telegraph, so that when "line clear" is signalled the telegraph is locked in that position until the train, when passing the outdoor signal, depresses a lever, thus releasing the semaphore arm, which in turn operates the block telegraph. This system, however, is not in general use. If the signalman's duties were merely routine work, this lock and block system might come into more general use, but as his duties are such that he cannot be merely an unthinking automaton, he is provided with a key by which he can disconnect this lock and block arrangement and act as necessity requires, and in this there may be possible confusion.

Apart altogether from these block systems, there is an

interlocking, at junctions, between the semaphore signal and the railway points, so that the signalman cannot lower his signal until he has moved the points, and he cannot put the points back again until he has put the signal to danger; but this is merely a mechanical arrangement.

The signalman usually supplies the energy required to move the outdoor signals and points, these being connected with pulling wires and moving levers, but there are now some places equipped with small electro-motors to supply the necessary movements.

CHAPTER XIII

FURTHER APPLICATIONS OF ELECTRICITY

An immense lift for an electro-magnet—Electricity gives gas a helping hand—Electricity on board a man-of-war—A note on Guy Fawkes—Blasting on a grand scale—Torpedoes—Recording the velocity of projectiles—Electric clocks—An electric log—Paradoxes of electricity—Electrocution—Quick news of the battle of Tel-el-Kebir—The untrustworthy telephone—Can fogs be dispelled?

IN steel and iron works large electro-magnets have recently been brought into use for lifting heavy metal plates, etc. Instead of fixing a chain and hooks around the plate, the crane merely carries a large electro-magnet at the end of its wire rope or chain, and this magnet attracts the plate and holds on to it as long as the current is kept switched on to the magnet. In the accompanying illustration a large magnet is shown lifting a heavy casting weighing about three tons, and on the same page may be seen an ordinary kitchen poker lifting scissors and keys, which serves to show the principle.

Electricity and gas are strong rivals as illuminants, but we sometimes find electricity giving gas a helping hand. When a large chandelier is out of easy reach and cannot be conveniently lighted by a taper, it is only necessary to arrange a short gap for an electric current to spark across, and to arrange that when the gas is turned on the electric

current is also momentarily switched on, and the gas thus ignited by the spark. This simple but useful application dates back to 1839, at which time few practical applications of electricity had been made. Indeed, I was rather surprised the other day on picking up a science book, published in London in 1840, to find the following statement: "It must be allowed, that the case has not been the same with electricity as with magnetism. The latter, by the invention of the magnetic needle, has served to render navigation more secure, and to discover the new world, a source of new riches, new wants, and of new evils to the old one. But electricity has not yet produced any thing of so much importance, to mankind, and to the arts, if we except the analogy now proved between the electric fire and lightning: an analogy which has given rise to a pretty sure preservative from the effects of that dreadful meteor; for in regard to the cures effected by electricity, it must be acknowledged that they are either rare, or not well ascertained."

What benefits we have reaped from the applications of electricity during the years that have passed since the above lines were first penned!

A steamer equipped with a powerful electric search-light is at a great advantage in many ways. We may take as an illustration an incident which happened some years ago on a British man-of-war, and may have been repeated often since the occasion referred to. The ship was steaming along on a very dark night when the cry was raised of "Man overboard." It is not difficult to realise the horror of those on board when thinking of the speed the vessel was making and the dense blackness

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A Magnet lifting a Casting weighing three tons. When the magnet is in position to lift, the electric current is switched on, and when the casting is at its destination the current is switched off and the magnet lets go, thus avoiding use of chains, etc. The illustration in top left-hand corner shows a kitchen poker doing the work of the magnet in the same way.

of the night. How many sailors are lost every year even from slow-going vessels because it is impossible to find the whereabouts of the lost man in the darkness! In the case of this British warship, two of her officers happened to see the sailor fall off the rigging, and both immediately dived into the water to the poor man's rescue. The great searchlight at once scanned the water, and soon revealed the three men clinging to a lifebuoy. The searchlight kept them in view while the steamer slowed down and swung round, so that the lifeboat was able to go straight to the men in the water, and it was reported that within six minutes the men were saved, the lifeboat hoisted, and the great ship once more on her way.

In time of war electricity now plays a very prominent part, not only as a carrier of intelligence, but as a prompt and sure assistant in the firing of guns and the exploding of distant mines. It is even made possible for the captain of a large warship to fire a whole broadside simultaneously, the commanding officer being able to see from instruments in his conning-tower when all the guns are set and ready.

Not only may submarine mines be exploded electrically by making a small platinum wire red hot, but much the same may be done on land. During the Russo-Japanese War we saw what a terrible disaster may be brought about by the enemy undermining a whole roadway, and then by electrical means firing the mine from any distance at the moment their opponents have reached the prepared spot, and in this heartless fashion practically annihilating a whole regiment.

It is very well that Guy Fawkes was born too early to

obtain assistance from electricity in the firing of explosives, or he and his friends might have succeeded in evading suspicion in connection with the vault they rented under the House of Lords. Having once secreted the thirty-six barrels of gunpowder unnoticed, they could have left the store closed, knowing that they would be able to fire the explosives from their adjoining house at the moment when Parliament had assembled. Even the anonymous and vague letter of warning might have failed, for it was only when the Lord Chamberlain saw "this very tall and desperate fellow" in charge of the vaults that his suspicions were really aroused.

Electricity has made it possible to fire very large blasts for clearing away rocks, etc. To form an adequate conception of this application of electricity, it is worth while picturing the great blasting operations which took place some twenty years ago in America, in the destruction of Flood Rock, in the East River, near New York. About nine acres of solid rock were undermined and honeycombed, and over thirteen hundred holes were drilled, in which were placed the explosives. Each dynamite cartridge was provided with an electric fuse, and a wire was run out and connected to a number of fuses in one particular section, and then back to the controlling station again, each section being arranged in this way. Then the ends of the leading-out wires were all brought together and placed in a vessel of mercury, while the ends of all the leading-in wires were placed in a second vessel of mercury. It only remained now to take a powerful battery, and place one wire in the mercury at the leading-out ends and the other wire in the mercury at the leading-

in ends, thus completing the circuit, and allowing the current to fly out to all these fuses in the dynamite cartridges, causing the simultaneous explosion of over 300,000 pounds weight of dynamite, etc., and blowing up many thousands of tons of solid rock.

The ordinary torpedo of naval warfare is purely mechanical, and has no connection with electricity, but is propelled by compressed air furnishing the necessary power to its engines. For harbour defence work electricity has been called into the service of the torpedo, as in the Sims-Edison torpedo, in which the power is conveyed by means of electricity from a dynamo on land or on board a ship, but the disadvantage is a long trailing cable, connecting the dynamo with small electro-motors in the torpedo.

It has been suggested to control the steering gear of torpedoes by means of ether waves, as used in wireless telegraphy. This has been found quite possible, and several patents have been taken out in this connection. Be it noted that the ether waves do not convey the propelling power, as some writers have set forth, but merely operate upon a "coherer," as in a wireless telegraph receiver, switching off and on the local power to the differential gear controlling the steering apparatus.

Electricity enables us to measure the speed at which projectiles are flying. An electrical contact may be placed at any point in the path of a projectile, so that the exact fraction of a second at which it passed this point may be recorded on a chronograph, as will be described in connection with "Electricity in the Observatory." A second contact-maker placed at any given distance will

note the time at which the projectile passes it, and in this way the time taken to travel from the one point to the other has been recorded. It is even possible to place two contacts at different parts in the bore of a gun, and thus find the velocity of the projectile before it leaves the mouth of the projector, and the time noted may be correctly measured to the $\frac{1}{5000}$th part of a second.

Electricity now aids in the measuring of time for everyday requirements, either in controlling the clock or in propelling it. In the former the swing of the pendulum is merely hastened or retarded by an electric impulse sent out every second by a standard clock to a large coil of wire, inside which a magnet swings, attached to the "bob" of the pendulum.

In the latest form of electrically driven clocks there is merely a dial with an electro-magnet and lever operating a toothed or ratchet wheel, moving forward the minute hand of the clock one step at each half minute, the hour hand being geared to this in the ordinary way. An electric impulse is received by the electro-magnet at every half minute through a large standard clock which closes the circuit once every thirty seconds.

It does seem rather ridiculous that we should be content to have in every city a multitude of little pieces of somewhat complicated mechanism, each little item trying to do exactly the same as its neighbour, and each requiring individual attention, supplying it with a store of energy once daily or weekly, while some skill is required to specially regulate each individual clock. Why not have one standard clock for every city, checked by the local or nearest observatory, and closing at the end of

each half minute an electric contact, allowing current to pass out to all the dials and thus move their respective hands forward one half minute.

It is even possible to have such dials fitted with a wireless "coherer" to catch ether waves, and switch off and on a local battery in the clock to operate its hands. I fear that any public clocks of this kind might pick up wireless telegraph messages and become rather eccentric in their behaviour. One could imagine a clock coming within the influence of waves intended for a wireless station, and if the message was a lengthy one, the public on consulting the wireless clock would think that time was literally flying. Here, again, these ether waves do not drive the clock, but merely control the driving power in the clock.

The uses to which the transmission of power by electricity may be put are legion. For instance, one may place the various parts of a large organ in any desired positions in a large hall or cathedral, keeping the echo organ at quite a distance from the other parts, while the keyboard may be put in any convenient place. In depressing the organ keys, the organist merely makes electrical contacts, thus allowing current to pass to the different electro-magnets opening the pipes.

Electric pianos have also been constructed, so that a pianist might perform from any distance, but this does not lend itself to any very practical use, more especially as we now have so many clever automatic pianolas, etc.

On board ship the log may be taken by electricity. The electric log consists of a "fly" or screw which is trailed after the ship, and revolves in proportion to the

speed at which the ship is travelling. This revolving screw is arranged to make an electric contact, thus working an indicator, or making a pen move over a revolving drum after the fashion of the wind velocity instruments to be described in the chapter on "Electricity in the Observatory."

A rather curious application of electricity is to be found in the hairdresser's establishment. He makes use of electricity either to destroy the roots of superfluous hairs, or to stimulate the growth of the hair. This may seem rather paradoxical, but what works in greater contrasts than electricity? It sounds an alarm at the outburst of fire, and thus protects from danger both lives and property, but it also most stealthily fires the submarine mine and sends a whole crew to the bottom of the ocean, sinking along with them a man-of-war costing, perhaps, a million golden sovereigns. Again, in the hands of the physician it will cure and save life, but in the hands of the executioner it will injure and kill. This last-mentioned application of electricity, which is now the method of executing the death penalty in the United States, has doubtless been somewhat unsatisfactory, owing to a restriction that the current used must not distort or disfigure the body of the criminal. In some cases death has not been instantaneous, whereas, but for the restriction just mentioned, it could easily have been made absolutely sure that death would ensue before the nerves could communicate any sense of pain to the brain. Given a free hand and electrocution would be the most humane method. What if the lifeless body were disfigured or even totally cremated by the electric current! Surely this would be infinitely better than our present

barbarous method of carrying out the death penalty in these islands!

Let us pass from this depressing subject to that of warfare. War must appear to all thinking people as a barbarous relic of the past, entailing the destruction of thousands of innocent lives over some national quarrel, based, it may be, on some misunderstanding; but even in warfare we may find electricity performing many peaceful as well as destructive acts.

All modern armies have their own telegraph experts, and it was found possible during the British operations in Egypt in 1882 to keep the advance guard, not only in constant communication with the headquarters, but with Great Britain itself. By this means the news of the victory of Tel-el-Kebir was telegraphed from the battlefield to the late Queen Victoria, and her congratulations were received in reply within three-quarters of an hour after the victory was won.

If any one had spoken of sending photographs by telegraph a few years ago, we should have thought the suggestion was made merely as a jest. It is impossible to send the actual photographs along the wire, but reproductions are made at the distant place. The photograph at the sending end is transparent and controls a beam of light passing through it. The varying light affects a selenium cell, causing it to alter its resistance to an electric current passing through it. The resulting current passes out to the distant station, where it controls another beam or pencil of light, which builds up a reproduction of the transmitting photograph. Full details are given in *The Romance of Modern Photography.*

Before closing this chapter, which does not attempt to include all the applications of electricity, I should like to mention two more. I have repeatedly read that the microphone, which is simply a sensitive telephone, is used by medical men as a delicate stethoscope, but from experiments I made in this connection many years ago on behalf of some medical men, I found that the sounds set up by every slight variation of the current in the microphone were a great disadvantage. Even a very clever mechanical stethoscope made on the Continent, while magnifying the sounds greatly, so that one can hear a friend's heart beat like a sledge-hammer, even through his overcoat, has not, I believe, proved a practical success for distinguishing the different internal sounds. It might serve as a quick means of discovering if there was any heart-beat in the case of an apparent death. I have seen it used for this purpose, but from inquiries I do not find that it has come into any general use. This mechanical stethoscope is much simpler than an electric one would be, so that there does not seem a reliable foundation for these repeated reports regarding them.

I think the case is very similar to one I had knowledge of some years ago. I had made up an electrical device, by which the cries of an infant in its cot would automatically ring an electric bell in the servants' quarters. I found it possible, but not a practical apparatus to be left in the hands of domestic servants, and so I altered it to a loud-speaking telephone, by which the cries could be heard at any distance. Having written a description of this suggested automatic alarm for one of the electrical journals, I was rather surprised when two years later a

friend drew my attention to a description of it in a popular magazine, wherein it was stated that the apparatus was in everyday use in America, which I knew was not the case. Possibly the article was copied in some American journal, from which it found its way again in a slightly altered form to a monthly magazine on this side, and on its way the misunderstanding had arisen.

Another application of electricity has reference to the deposition of smoke and fog. It has long been well known that a hot body will repel dust particles in the air while a cold body will attract them. This is easily proved by a very simple experiment. If a globe of hot water and a globe of cold water be placed under a glass cover and some magnesium ribbon be burned inside the cover, it will be seen that the dust particles all gather on the cold globe, while the heated one remains dust-free. It was found that if a platinum wire were heated by an electric current in the smoky air of a glass jar, the air became clear and the dust was quickly deposited on the inner surface of the jar. It was proved later that the same effect could be produced by electrifying the air, for a high-potential electrical discharge inside the jar soon cleared the air of dust. This has found a practical application in depositing the harmful fumes in lead works.

As a dust-laden atmosphere is necessary for the formation of fogs, mists, clouds, or rain, it is evident that by electrifying the air and depositing the dust we should clear the atmosphere of fog. To do so in a wholesale fashion would doubtless cost a ransom, but Sir Oliver Lodge suggests that this might be done at important

centres where the fog is most dangerous. While the Principal of Birmingham University suggests this method, he does not believe it to be the right remedy any more than free meals and free doles are a sound remedy for the problem of poverty, but in the absence of a better remedy it is worth a trial.

Electricity has been applied in agriculture also. The origin of the latest plan is of interest. Professor Lemstörm, of Sweden, was making some electrical experiments to imitate the Aurora Borealis. He made these in his greenhouse, and he observed that the plants in the neighbourhood of his apparatus seemed to thrive exceptionally well. This led him to try the effect of similar high-tension discharges upon fields of growing grain. The necessary current is now obtained by means of a dynamo and induction coil, and the discharge is made from a network of wires erected over the field. The appearance is that of several rows of telegraph poles, there being about one hundred yards between each row. The wires on these carry the main charge, while finer wires connect the parallel wires together every twelve yards. Wheat grown under electric discharges has yielded an increase of thirty and forty per cent more than that from part of the same field unelectrified. The wires may be placed about fifteen feet above the ground, and the poles are so far apart that there is no difficulty in carrying on the ordinary work of the field. The cost of supplying the necessary current, apart from the first cost of the installation, is very small. It practically means the cost of running a small oil-engine or other motor for driving the dynamo.

CHAPTER XIV

ELECTRICITY AND SPEECH

What speech is really—How electricity produces sound—Useful invention by a clergyman—How telephone exchanges are worked—Some amusing ideas—Central-battery system—Clever signalling apparatus—The "howler"—Who keeps a note of subscriber's calls?

SOME people are content to go through life without ever stopping to think how it is that we can produce speech. The whole subject of sound, which branch of science is called *acoustics*, is a most interesting one to every one who cares to study it.

It is known to all that when a body produces or emits a sound such a body must be in vibration in order to disturb the surrounding air and set up similar vibrations in it, which in turn strike upon the drums of our ears and cause certain sensations to be conveyed by our auditory nerves to the sensorium. The setting up of such air vibrations is very apparent in the beating of the big drum, the clapping of cymbals, the striking of a piano key, the bowing of a violin string, and so forth. Again, we have the vibrating reeds in many wind instruments, and in others, such as flutes and trumpets, we have a column of air in vibration.

The air being matter in a gaseous state, is made up of tiny little particles or molecules, and it is each of these

molecules of gas, far beyond even microscopical vision, which vibrates to and fro. As each little molecule has, as it were, to nudge his neighbour into motion, it is natural that the energy thus transmitted soon dissipates itself, so that the molecules at a distance do not receive any appreciable disturbance unless the sounding body is in very violent vibration, and even then the sound soon dies away in the air as the distance increases. As a matter of fact, the air does not conduct vibrations (sound) nearly so well as a liquid, which has much greater elasticity; and on the same principle a solid is a better conductor of sound than a liquid. The string telephone, which although merely a child's plaything is yet of much scientific interest, is a good illustration of a solid body (the string) conducting sound better than the surrounding air.

Early in last century a London professor gave a very good illustration of this property of solids to an audience in the Polytechnic Institution in London. A band of musicians were placed in a room in the basement of the building, and from this room long solid metal rods were carried right up through the principal hall and into a room on the upper floor, where they were attached to ordinary sounding boards, a number of rods and boards being used simply to increase the effect. When the musicians played in the basement the audience in the upper room heard the music as clearly as if it were being performed there, but in the principal hall, through which the rods passed, no sound was heard.

This illustration enables one to realise what a good conductor of sound a metal rod is; but it is quite evident

that these vibrations when handed on from one to another of myriads of molecules will soon dissipate as the length of the rod is greatly increased; and in addition there will be a certain amount of damping or lessening of these vibrations at each point where the rod is supported. It was really in connection with this set of rods and boards just described that the word "telephone" was first invented, in order to express the idea of carrying sound (Greek, *phōnē*) to a distance (Greek, *tēle*)

It is quite possible to have a speaking telephone of this nature over a limited distance. In such a telephone we have a metal disc against which one person speaks, while the distant listener stands opposite a similar disc, the two metal plates or discs being connected by a tightly stretched wire. It is marvellous that a flat metal disc, receiving vibrations conveyed by the wire from the distant disc, can set up exactly the same vibrations in the air as the speaker's voice does at the other end. It is, indeed, an extraordinary feat on the part of a piece of flat metal to reproduce all the variety of air vibrations for the production of which we require the complex machinery of lungs, vocal cords, mouth, teeth, tongue, lips, and nose. It is evident that if the proper vibratory motion can be given to a metal disc, by any means, the disc will speak. The required vibrations are far too complex to be imitated by any purely mechanical arrangement, although an American, some twenty years ago, did construct a speaking machine, by closely imitating the arrangement of our human organs of speech. While the machinery was most ingenious, and was controlled by a keyboard, similar to that of a piano, but used for the opening and closing of

valves, etc., and while the results were most remarkable, yet many words were very indistinct, and all the sounds were too uniform and drawling. The only way in which we can give a metal disc the proper vibrations is by either directly speaking in front of it, or by communicating to it these vibrations already given to another disc.

In the phonograph we speak against a very thin glass disc or diaphragm, which, by means of an attached cutter, makes little indentations on a rotating cylinder of specially prepared wax. The disc may again be made to reproduce the speech by rotating the cylinder and allowing the point of a connecting lever to bob up and down, as it were, in the indents, and thus set the attached disc once more vibrating, exactly as it did on the first occasion when influenced by the speaker's voice.

We can now imagine one metal disc in London vibrating in sympathy with a similar disc in, say, Glasgow, provided we can pass on the vibrations from the one disc to the other. Of course, a direct connection of a stretched wire of vibrating molecules is quite out of the question, as already explained, but a very simple way out of the difficulty is found with the aid of an electric current. The speaker talks against a little disc of iron, which we may imagine as being a somewhat elastic lid to a metal box filled with powdered carbon. The current on its way from a battery to the line wire has to pass through the carbon; it is as though a short piece of the wire had been cut out, and this box of carbon inserted in the space. The powdered carbon offers a great resistance to the passage of the current, but if the carbon is compressed, even very slightly, it permits more current to

pass, and the speaker, by speaking, sets up air vibrations, and causes such pressure on the disc and the enclosed carbon. The variations of this pressure cause an ever-varying current to pass out from the battery through the carbon and along the line wire. One may imagine it as an undulatory current having great variety of waves, and

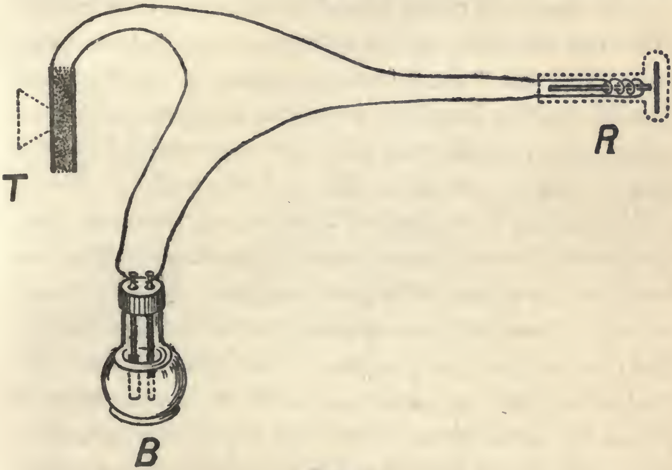


FIG. 9

THE PRINCIPLE OF THE TELEPHONE

The current from the battery (B) passes through the powdered carbon in the transmitter (T) and goes over the line wire to the distant receiver (R). The current is controlled by the vibrations of the transmitter, as explained in the text.

when this reaches the distant end of the wire, it is led through the small coil of an electro-magnet, in front of which is placed a metal disc, similar to that in the transmitter at the sending end. The metal disc will be attracted by the electro-magnet in degree, according to the current passing. In this way the disc in the receiver

is set into motions exactly similar to those of the disc at the speaker's end. When the listener places the little disc close to his ear, the disc in turn sets the air into exactly similar vibrations to those which the speaker is producing in front of the sending disc, and therefore the speech is heard just as though the speaker's voice was directly operating on the listener's tympanum or ear-drum. We have, therefore, in the telephone the speaker's voice controlling the battery current, which, on reaching the distant receiver, produces a varying magnetic field, thus influencing a little iron disc, and thus setting it into exactly similar motion to the controlling disc.

This is only a very general description; there are other details which we need only mention in passing. When the telephone is supplied with electricity from a small primary battery, the current passes through a small induction coil and is intensified in pressure. Then there is the little electro-magnetic machine (a small dynamo), which is driven by a handle, and sends out a powerful current to operate the receiver's bell. As this bell is only for calling attention, it is automatically switched out of the circuit while speaking. When that part of the instrument carrying the transmitter and receiver is lying at rest on its stand, the end of the line wire is in contact with the bell circuit, but as soon as the speaking part is lifted the holder rises by a spring, and in so doing it switches the line wire to the telephone proper.

In the first form of telephone in which this powdered carbon was used, the little metal box, or case, containing it was fixed to the wall instrument, and as the powder would keep gravitating to the bottom of the enclosing

case, the speaker was requested to shake or turn the case occasionally. Such instructions are very apt to be overlooked, but by fixing the transmitter in one piece with the receiver, which was formerly the only part one hung up and took down to operate the switch, the speaker is made to shake up the carbon in the transmitter each time he uses the instrument without receiving any instructions to do so. By improvements recently made in the transmitter it is now unnecessary to move or turn it in any way to maintain its efficiency. It is of interest to note that this transmitter with the granular carbon, which is now in full command of the field, was invented by an English clergyman named Hunnings. Two other very useful inventions made by clergymen are the power-loom and the hosiery-machine.

At the time of writing the first edition of the present volume, each telephone in use in this country had its own primary battery beside it. But in America it had been suggested many years previously to supply all the current from a central battery at the exchange, and dispense with the individual batteries at the subscribers' instruments. In this connection the following remark was made in the first edition: "It seems probable that all telephones will someday be worked from a central battery at the exchange, although this system has not found much favour as yet." Since that time many exchanges have been arranged on the central-battery system with complete success.

Through the courtesy of the National Telephone Company in Glasgow I have had an opportunity of seeing the working of one of the most modern exchanges on the

central-battery system. Before describing this exchange, a few preliminary remarks may be helpful.

Originally the telephone was used merely for speaking between two particular places, just as an ordinary speaking-tube is used. It may be mentioned in passing that the general public looked upon the telephone as a scientific toy at first. However, it soon became apparent that if all the telephone lines passed through one public office, it would be possible to connect any two of the distant instruments together. Prior to this time the Post Office had given intercommunication between private telegraph lines using the old A B C dials. No doubt it was this fact that suggested the Telephone Exchange.

The first exchanges were very small, so that the connecting arrangements were very simple. The telephone users became known as *subscribers*, as they had to pay a subscription or rent to the company who supplied the telephone instruments and undertook to make all the necessary connections so that they could converse with all the other subscribers.

When one wishes to be able to connect a portable electric lamp to several places in a house, one gets the electrician to bring the ends of the wires, carrying the current, to a convenient position on the wall. The wires are then attached to two little sockets, and the portable lamp is provided with two small fingers or plugs which fit into these sockets, and can be withdrawn at will. The same idea is made use of in connecting one pair of telephone wires to another pair.

In the early days only one wire was used for telephony, its two ends dipping into the earth at the extremities

By permission of *The National Telephone Co., Ltd.*

A MODERN TELEPHONE EXCHANGE SWITCH-ROOM

The operators, who make all the connections between the different subscribers' telephones, are seated around the switch-room. It seems incredible that each of these operators, without rising from her seat, can connect a subscriber to any one of the ten thousand subscribers whose lines enter this exchange. This photograph will be of interest along with the description in the text.

just as telegraph lines of the present day are arranged. All the subscribers' wires were finished off with a little socket or "jack." These jacks were arranged close together in a table. When the exchange operator was asked to connect one subscriber to another, she used a short length of flexible wire having a plug on each end. Placing one plug in the jack belonging to the first subscriber, and the second plug in that of the other subscriber, she united their wires and enabled them to carry on conversation.

In the early days, when there were only a few hundred subscribers, a telephone exchange was comparatively simple. A modern exchange may have to deal with as many as ten or twelve thousand subscribers, and in order to provide means of connecting together any two of that great congregation of wires, a great deal of ingenious planning has been necessary. It will be of interest therefore to see the working of a modern exchange.

I may remark in passing that it will be apparent to all that a subscriber cannot call to an operator, "Please connect me to Mr. John Smith." The subscriber must look up the *Telephone Directory* and state merely the number by which Mr. John Smith is known. We are just so many numbers to the telephone operator.

Until within recent years, one was able to recognise a telephone exchange by the great congregation of wires over the top of the building. To-day there is no such conspicuous sign, and one might pass a modern exchange without suspecting that it was such. This change is not accounted for by the advent of wireless telephony, which by the way will occupy a special field of its own, and as

far as one can see at present it will not come into competition with ordinary telephony. The reason of the change referred to is much simpler. It is merely that the congregation of wires has been carried along under the ground instead of overhead. There are many advantages in this change.

Each cable may contain as many as twelve hundred wires. These are all carefully insulated from one another and protected on the outside by a heavy lead tube. It is common practice to have six hundred, or even eight hundred pairs of wires in one cable. Each subscriber requires a pair of wires to give a complete circuit for his telephone, as the original plan of an earth circuit has been dispensed with, as already mentioned.

I have been amused in noting the different ideas that friends have formed of the interior of a telephone exchange. Some have even pictured a large hall with a multitude of telephone instruments, each instrument representing the exchange end of a subscriber's wire. However, most of the public have clearer ideas to-day. Photographs of the interiors of some exchanges have been published in the public journals.

We are all familiar with the subscribers' instruments in their homes and offices. We may picture the wires from six hundred different subscribers' instruments all coming together and passing into one cable which is buried under the streets. The other end of the cable comes up under the telephone exchange. Here we find several similar cables coming through the floor of the *apparatus-room*.

The amateur electrician finds it quite a task to separate

the ends of a small cable containing half a dozen wires and find the two ends of the same wire. Imagine what it must be to separate a cable of twelve hundred wires!

The first thing the telephone engineer has to do is to separate these wires and fix the end of each wire to a suitable connection upon one side of the "main-distributing frame." He takes the wires just as they come without considering the number of the subscriber. After getting these securely fixed, he attaches to each certain safety devices. There is some risk of a telephone wire getting in contact with an electric-light wire and conducting a heavy current into the exchange. Two of the safety devices are to protect the apparatus in the exchange against the entrance of any such current. These protectors consist of a *fuse* and a *heat-coil*. They give way under the heat produced by a heavy current, and as soon as they break they cut the circuit or send the intruding current to earth. The third safety device is to protect the exchange apparatus against lightning, should it happen to strike a telephone wire. This *lightning-arrester* consists essentially of a small air-gap across which the lightning charge can jump to an earth wire, whereas the ordinary telephone current cannot cross this air-gap, and has to keep to its continuous path. The lightning, on the other hand, finds it easier to take this short cut to earth rather than go through the apparatus in the exchange. The difference of behaviour between the battery current and the lightning discharge is due to the fact that the former is impelled by a low electrical pressure, while the electrical pressure of the latter is millions of times greater.

After getting each wire securely fixed with these safety devices, the wires are continued over to the other side of the distributing frame, each wire being taken from this point to a second frame in numerical rotation. No. 1 subscriber's wire is now in the first position on this frame, and so on with the others. These are extended to a third frame carrying apparatus the use of which we shall understand better when we have seen what is taking place in the *switch-room*, where all the connecting and disconnecting of the subscribers' lines is carried on.

When we enter this room we see an upright board extending right round the room. (See photograph facing page 146.) This is the board which holds all the little sockets or "jacks" representing the ends of the subscribers' wires.

We find the operators sitting in a row around the room, facing this upright board, as may be seen in the photograph. Each of these young ladies has a very light telephone receiver held against her ear by a suitable fastening around her head. The transmitter of her telephone, which is supported by a light frame hung upon her shoulders, has a long funnel coming close up to her mouth. Standing in the switch-room, one scarcely hears that any conversation is taking place at all.

First of all we had better get a general idea of the operators' duties. They are to attend to all the calls made by the subscribers and make the necessary connections between subscribers, disconnecting them when requested. An operator must be able to connect the subscriber calling with any number requested. This means that each operator must be able to reach from No. 1 socket or jack to

No. 10,000. It is necessary on this account to bring all the jacks into as small a space as possible, consistent with efficient construction. The space required makes a board opposite which three operators may sit with comfort and yet so arranged that each may reach to any one of the ten thousand jacks on the board.

While each of these operators could connect any two of the jacks with a flexible cord, it must be clear to all that these three operators are not going to attend to the calls of the whole ten thousand subscribers. One hundred subscribers will keep an operator fairly busy, but she can connect any of these with every other subscriber asked for.

To answer the calls of the whole ten thousand subscribers will require about one hundred operators each attending to about one hundred subscribers. There is nothing for it but to fit up duplicate boards each containing the whole subscribers' jacks, and let every three operators have a complete board. We may picture the pair of wires of No. 1 subscriber coming up from the apparatus-room and entering the switch-board; at the first section they are fastened to No. 1 jack, then passing on to the next section they are fastened to another similar jack also marked No. 1. So on the wires go through the whole long board around the room, being tapped at each section and connected to a socket or jack fixed there. The whole arrangement is called the *multiple board* because of this multiplication of jacks for each subscriber's line.

We are ready to see how the subscriber is to communicate with the operator. Several different plans have been tried. I can remember in the early days we used to go forward to our telephone instruments and

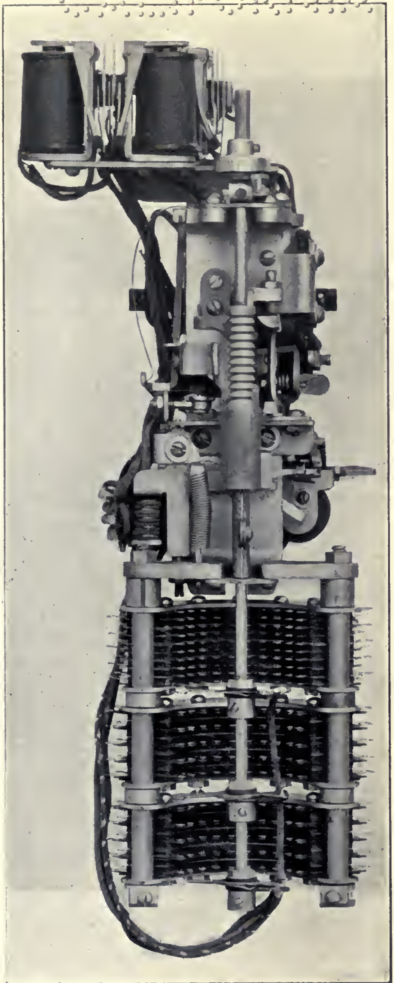
"ring up" the operator. That is to say, we turned the handle of the little magneto-electric machine just as we did when ringing a subscriber after being connected. Some subscribers fondly imagined that they were actually ringing a bell in the exchange, and if they did not get immediate attention they would continue to "ring like a house on fire." I used to ask these friends what sort of pandemonium they thought a telephone exchange must be like. Imagine hundreds if not thousands of bells all ringing at one time in one room. These impatient subscribers were quite disappointed to learn that all their high-pressure energy merely caused a very small lever to drop the shutter of a little indicator and expose the number of the subscriber making the call. After this almost noiseless operation was performed, the remainder of the current which was intended to waken up the operator merely caused the tiny lever to move a small fraction of an inch.

Another plan adopted to give subscribers a prompt means of communicating with the operator was to have the operator always listening on a public call-wire. This wire passed through a certain section of the town, and branch lines were dropped from it into the subscribers' offices or homes. As many as sixty subscribers would be connected to one call-wire. The telephone instruments were not connected directly to this wire, but as long as the subscriber depressed a button on his instrument he switched his telephone on to this public call-wire. The advantage was that he could get in touch with the operator at any moment. The disadvantage was that a number of subscribers might all attempt to give calls at the same

By permission of the Automatic Electric Co., of Chicago.

HOW AN AUTOMATIC TELEPHONE WORKS.

(1) In Automatic Telephone Exchanges there are no operators. Every subscriber has an instrument as shown in the above illustration, and if he wishes to be connected, say, to subscriber No. 357, he merely places his finger into the hole marked 3 and turns the dial round as far as it will go. He then does the same with Nos. 5 and 7, and is then connected through to the other subscriber.



By permission of the Automatic Electric Co., of Chicago.

(2) At the Exchange end of the wire is a very ingenious piece of apparatus called a Selector, as shown in the photograph. Every subscriber's line has one of these selectors, whose duty is to make the necessary connection, which it does without the usual girl operator.

time, and unfortunately many of them seemed to think that whoever would cry the loudest would get the best attention. The result was that the poor operator was often at her wits' end to make head or tail of the jumble of noises. This call-wire system is most convenient in districts where the subscribers are not too numerous and where there is no great rush of business.

Another plan was to give each operator an *answering jack* for each subscriber to whom she had to attend. These were sockets or jacks similar to those in the multiple board, but additional to them. These answering jacks were grouped together below the others right in front of the operator. Beneath each answering jack there was a tiny electric glow lamp, in diameter about the size of a large pea. At the other end of the line the subscriber had a button on his instrument, which if depressed caused the little lamp in the exchange to light up. In this way the operator knew when any of her one hundred subscribers wanted to speak to her.

The latest plan is really an improvement on the last-mentioned. The operator still has the answering jacks and the little signal lamps, but things have been made very easy for the subscriber. He has not to trouble about any signalling. He merely lifts his telephone off the hook, and this action causes the signal lamp to glow. With the latest methods the operator is able to answer within five seconds, so the subscriber will doubtless think she has been waiting his call just as the operator on the call-wire used to do. Indeed, one gentleman using this new system has told me that the operator answers so quickly sometimes that he suddenly forgets what he was about to say.

It is worth while enquiring what really happens when the subscriber lifts his telephone off its support. The support, being freed of the weight of the telephone, springs up and completes the subscriber's circuit with the exchange. This causes a current from the large battery at the exchange to operate a signalling instrument attached to the subscriber's line, on the third frame mentioned, in the apparatus-room. This little signalling instrument, called a *relay*, consists of an electro-magnet which attracts an armature to it and thus switches on the necessary current to light up the small lamp beside his answering jack on the operator's board. As long as the subscriber keeps his telephone off the hook the little relay in the apparatus-room will keep the current switched on to the lamp.

When the operator inserts the plug, which is attached to one end of her connecting wire, into the answering jack, this lamp goes out. The insertion of the plug in answering the call puts current on to a second relay arranged beside the first one in the apparatus-room. This switches the current off the first relay, causing the lamp to go out as mentioned, and the insertion of the plug at the same time brings on the necessary lighting current for the signalling lamp representing the connecting wire. There are two lamps, one representing each side of the connecting wire. The two ends of this connecting wire come up through the operator's table and the plugs stand upright in front of her. The flexible wire hangs down beneath the table until the plugs are lifted, when it comes through the table. A weight suspended beneath the table keeps the flexible wire always

taut, and pulls it back through the table when the operator frees the plugs from the jacks.

So far the operator has used only one leg of the connecting wire. She has inserted this in the answering jack, whose light glowed. By moving a small lever into what is called "the listening position" she switches her own telephone on to the calling subscriber and learns from him the number of the subscriber to whom he wishes to speak. The operator now lifts the second plug on the connecting wire and puts it into the jack of the number wanted. She then moves the little lever from "the listening position" to "the ringing position," and this causes an electric current from the apparatus-room to reach the subscriber's telephone and his bell rings. The ringing current is supplied by a generator driven by a motor. The operator holds the key over to the ringing position for a second or so, then releases it. Until the subscriber wanted answers the ring thus given, the lamp on that side of the connecting wire glows, but immediately he takes the telephone off the hook the lamp goes out. This gives the operator intimation that the subscriber wanted has answered the call. The operator knows that both subscribers have their telephones off the hooks, and she leaves them connected.

If one lamp glows while the other remains out, she still leaves them connected, for very probably one subscriber has merely put down his telephone while he goes to make some inquiry. When both lamps glow, this is accepted as the signal to disconnect. The operator is entitled to presume that they have finished as they have both laid down their telephones. She therefore withdraws the connecting plugs.

It will be observed that the subscriber has not to "call off." This is always a trouble in other systems, for a subscriber omitting to call off is supposed to be "engaged." The only possible chance of a subscriber being left "engaged" after he has finished is if he goes away and leaves his telephone off the hook. Even this contingency is provided for. It would seem hopeless to get him, as the operator cannot ring his bell so long as his telephone is off the hook. She reports the matter to a test clerk, who switches on "the howler." This produces a howling sound, not unlike a syren, in the subscriber's telephone. This calls the attention of the subscriber to his carelessness in leaving his telephone off the hook.

It is obvious that two subscribers at different boards may call for the same number at the one time. What is to prevent an operator connecting a third party to a line already in use? She can tell by touching the subscriber's jack with the connecting plug before she inserts it. If she hears a clicking sound in her own telephone she knows that the line is already connected elsewhere, so she intimates "engaged sorry" to the subscriber asking for the number.

Other operators, at a separate table, deal with connections to other exchanges, but we need not trouble with more detail as the general principle is the same as that just described. There is, of course, this difference, that the two subscribers' jacks which are to be connected lie in different exchanges. This necessitates the use of a junction line, one end of which is in the one exchange and the second in the distant exchange. These calls are described as *junction calls*. One interesting feature in

connection with these calls is that when the operator puts down the key to ring the subscriber wanted, it is automatically held down. It is so arranged that the ringing current from the generator is cut off and put on at the end of every few seconds, after the manner of some alarm clocks, until the subscriber wanted lifts his telephone off the hook. Immediately he does this the current which holds the key down is automatically switched off and this in turn cuts off the ringing current. In this way the operator's time is not wasted waiting the reply of a dilatory subscriber, while the bell of his telephone continues to ring until he answers. Then there are *trunk calls*, which signify connections requiring to be made between two subscribers who are in different towns. A subscriber in London may converse with a friend in Scotland or France, and so on.

There is one point which is sure to be of interest to telephone users. Instead of renting the telephone for a certain annual subscription, it is becoming common to charge so much per thousand calls. How in the world is an operator going to keep count of all the calls each of her one hundred subscribers makes in a day? She is kept busy enough connecting and disconnecting subscribers without attempting any system of book-keeping. Again the obliging automaton comes to her assistance. Down in the apparatus-room each subscriber's wire is provided with a tiny meter or register. Any one who is familiar with the small cyclometers put upon cycle wheels, for counting the mileage, will understand the general principle. A train of wheels turns the figures on an indicator. But the meter must not work every time the subscriber lifts his

telephone off the hook to call the exchange. The number he wants may be engaged, and he will not be willing to pay if he has not obtained the connection he asked for. It is the operator, therefore, who actuates the meter. When a subscriber has got his message through, the operator depresses a small key or button in circuit with the connecting wire she is using. This sends a current to the meter of the calling subscriber and registers one call against him. The telephone subscriber therefore pays for his calls on the same principle as he pays for his gas or electricity.

Each operator has also a meter which registers the total number of calls she attends to each day. This, however, is merely for the use of the telephone manager.

It will be remembered that there are no batteries at the subscriber's telephone. The whole of the necessary current is supplied from the exchange. About one dozen large accumulators serve for everything. These are charged by means of suitable dynamos. One advantage is that, no matter how long a conversation may be continued, the current remains constant. The primary battery, on the other hand, used to give trouble, as its current fell off very quickly if kept too long on the line without a rest. There is no doubt that the central-battery system has come to stay—at least until some other newer method makes its appearance.

In the United States of America there are several telephone exchanges which are worked without human operators, the connections and disconnections being made automatically. One of these exchanges has eight thousand subscribers.

The method of calling a number will be understood by referring to the left-hand illustration facing page 152. The legend below the photograph will explain the action. The electric impulses sent out by the subscriber in calling the number desired operates a *selector*, the construction of which is shown in the right-hand photograph on the same page.

When the subscriber signals the number of hundreds in the directory number of the subscriber he wishes, the centre rod in the selector moves up three sections if the number signalled is in the three hundreds. This upright rod carries with it a little arm or finger which is to make connection with the other subscriber's line. At present we have imagined it to be raised to the section containing all the numbers beginning with three hundred. The next set of impulses from the calling subscriber moves the little contact finger to the flat or row containing the number wanted. If it is among the fifties then five impulses are received, and that raises the finger to the fifth row. The next set of impulses representing the units cause the rod to turn round and bring the finger along the row to the first, second, or whatever number is required among the fifties. Thus if the subscriber signals the numbers three, five, and seven successively, the connecting finger will rise to the third hundred, the fifth row, and the seventh line in that row; his telephone will be connected to No. 357.

When the subscriber who originated the call puts his telephone back on the hook, the automaton disconnects the line by allowing the upright rod in the selector to return to its former position of zero. The disadvantage

in a purely automatic exchange is that the Company lose all control of the system. To take an illustration, we may suppose that subscriber A is a rather eccentric individual, and because he has a grievance against subscriber B, A connects his telephone to that of B, but does not ring him. So long as A leaves this connection, of which B is not aware and which he could not disconnect, so long will no one else be able to call B. In other words, one subscriber can purposely hold up the line of another subscriber to the disadvantage of the latter.

There is now a telephone which might, by the uninitiated, be supposed to possess brains, for if its owner is absent when a friend rings him up it will accept the message on its own account, and repeat it to its master on his return, and no matter how long he is in returning, or how many friends have confided messages to it, it never suffers from loss of memory, but gives a correct recital of all the information or secrets that have been entrusted to it.

This instrument is called a telegraphone, and its general principle may be briefly stated. If one pictures for a moment the telephone transmitter sending out a varying current to the distant magnet, as described in the earlier part of this chapter, and if one recalls how the magnet acted upon the disc or diaphragm, then we have only to replace the stationary disc by an iron wire passing in front of and slightly touching the magnet, the wire being thus magnetised by the influence of the electro-magnet, which is varying under control of the speaker's voice. The wire therefore receives, as it were, a great number of spots

of different degrees of magnetisation, which it is capable of retaining, the wire being made of mild steel. The wire is now analogous to a phonograph cylinder with a record upon it. The reproduction of the sound is very easily understood if one imagines the little magnet of a telephone receiver, instead of being magnetised by the incoming current from a distance, being now merely put in contact with this magnetised wire, which, when drawn across the electro-magnet, imparts similar degrees of magnetism to it. The magnet, thus influenced, will in turn operate an ordinary telephone diaphragm, and thus set up similar air vibrations to those originally imparted to the telephone that used the wire as a record.

As the telegraphone is now a reliable piece of apparatus, there may be quite a large commercial field for it. How much more reliable to have a clear-headed instrument accept a message and redeliver it instead of having to cross-examine a careless servant as to whether Mr. So-and-so said this or that.

CHAPTER XV

WIRELESS TELEPHONY

The telephone receiver in wireless telegraphy—Early attempts at transmitting speech—Speaking along a beam of light—Speech transmitted between two parallel wires—The latest methods.

WHEN considering the different methods of picking up the signals in wireless telegraphy we saw that one convenient arrangement included a telephone receiver in which the operator heard a series of clicks representing the Morse code. This arrangement led to some confusion in the early days of wireless telegraphy. Newspaper reporters and others seeing these experiments believed that speech was being transmitted.

At that time most of us had no great faith in wireless telephony coming into practical use over any long distance. It was one thing to send signals by means of sudden disturbances in the ether, such as those waves produced by a torrent of sparks, but it required something better than that to transmit the more delicate alternating current used in telephony. Indeed, if we had to depend entirely upon the spark method of transmission, we could not have produced an efficient wireless telephone. With the introduction of continuous trains of ether waves, however, it became possible to transmit articulate speech.

It is true that a wireless telephone existed before the

days of wireless telegraphy, but as this consisted practically in speaking along a beam of light, it was evident that the distance over which this might be used must be very limited. It seemed as though this method could remain only an interesting scientific experiment. This principle has been adapted for short ranges—such as between ferry-boats and the shore.

The general principle of the foregoing may be of some interest. The telephone had not been invented for any length of time, when it was discovered that speech might be transmitted along a beam of light. The beam of light, either sunlight or electric arc light, is focussed on to a little flexible mirror, made of silvered glass or mica. The speaker's voice causes this little mirror to vibrate, just as though it were the disc or *diaphragm* in a telephone transmitter. The vibrations of the mirror disturb the beam of light which it reflects towards the distant receiver, where it falls upon a selenium cell. This cell possesses the strange property of altering its electrical resistance in proportion to the amount of light falling upon it. We may picture the selenium cell as being somewhat analogous to an ordinary bell-push, but infinitely more sensitive. You may press a bell-push and allow the current to pass, or you may let go the push and stop the current, but the selenium cell allows different amounts of current to pass according to the amount of light falling upon it. If only a little light falls upon the selenium, then only a little current is allowed to pass. An increase in light means a corresponding increase in current. By this means the varying beam of light controls the current in the telephone receiver, so that the

vibrations of the little mirror at the speaking station are imitated by the diaphragm in the telephone receiver. In this way the original speech is reproduced at a distance.

It is interesting to note that in the experiments made with this light-telephony it was found possible to speak from both stations simultaneously, the two beams of light not interfering with one another. Speech has been transmitted over a distance of about eight miles by this method.

There is one point which might appear to be a difficulty. How is the sending station to focus the beam of light on to the receiver of a moving ferry-boat? This difficulty is not a real one, for the beam of light will have spread out to a breadth of several hundred yards if the distance be great. The action is all the more remarkable as only a very small portion of the beam of light will reach the receiver. It is quite obvious, however, that the maximum distance over which this system may be used cannot exceed a few miles.

In the chapter on wireless telegraphy I have referred to the early system used by Sir William Preece. It will be remembered that the principle was one of induction between two long parallel wires, one at the sending station and the other at the receiving station. It was found possible not only to send signals, but to transmit actual speech over a distance of several miles.

The electric current sent out by the telephone transmitter is a to-and-fro or alternating current, so that every variation of current in the long transmitting wire induces a corresponding current in the distant parallel wire at the receiving station. The one disadvantage is

that the length of the parallel wires has to be increased as the distance between the stations is increased.

An installation upon this plan has been at work for many years between the lighthouse on an island called *The Skerries* and the mainland on the coast of Anglesey. The distance is a little short of three miles, and under ordinary circumstances one might think it best to lay a submarine cable. But the sea-bottom at this point is so rough and the tidal currents so strong that a cable would be quite useless. The island is a small one, but it was found that a short wire of less than half a mile on the island, with a parallel wire of about three and a half miles on the mainland, was sufficient to give good induction between the stations. The convenience of being able to carry on ordinary conversation between the lighthouse and the mainland will be appreciated.

While the ordinary spark discharge was useless for transmitting speech, it was found that by more rapid sparking arrangements much better results could be obtained. But the great strides which have been made in wireless telephony are not based upon a spark discharge. A continuous emission of ether waves is produced by rapid electric oscillations in an aerial wire, and this emission is controlled by the speaker's voice. What happens is this.

We have two persons separated from each other by many miles, and without any connecting wires between the two places. One of the men speaks into a telephone transmitter, the connections from which end in an upright aerial wire at his own station. At the distant station the second man listens at a telephone receiver connected to a

similar and local aerial wire. The speech is transmitted between these two aerials in the form of ether waves. The diaphragm in the telephone transmitter sets up a to-and-fro current in the ordinary telephone circuit, and this current is made to act upon another neighbouring circuit, in which a high-frequency current is continuously surging. The variations in the telephone current cause similar variations in this powerful current. These electric oscillations are conducted to the aerial wire, and in this way the surrounding ether is disturbed. Those ether waves travel out towards the receiving station, and are intercepted by the aerial wire at that distant place. There they affect a suitable wave-detector, such as an electrolytic cell. By this means a local battery current is controlled, and this actuates an ordinary telephone receiver. In this way the original speech is reproduced.

Some wireless telephone companies have been guaranteeing distances up to one hundred miles for several years back. It is now possible to speak over a distance of about two hundred miles.

As proof of the importance of wireless telephony, I may state that the United States Navy have equipped a number of their battleships with installations for speaking up to distances of twenty-five miles. For greater distances more power would be required. The problem of tuning to prevent interference is of even greater importance in wireless telephony than in telegraphy.

CHAPTER XVI

INDUCTION COILS EXPLAINED

What induction means—How an induction coil works—What happens in the coil—An analogy—Modern improvements.

IF one holds on to the handle end of a poker while the other end is placed in a fire one soon feels considerable heat passing to the hand, till the metal ultimately becomes too hot to hold any longer. We may say that the poker has conducted heat from the fire to the hand, and in the same way we may think of the telegraph wire conducting electricity from the battery to the distant telegraph instrument. In these connections we speak of the conduction of heat and of electricity; but we receive heat from the sun over a space of millions of miles in which there is nothing to conduct the heat. As more particularly stated in another chapter, we receive the heat from the sun by means of the ether, which does not conduct heat at all. We picture the heat of the sun setting up waves or vibrations in the ether, which in turn sets up heat on the earth. We might say that the heat in the sun induces heat in the earth, and in the same way we find electricity in one body inducing electricity in a neighbouring body with which it is not in contact.

In speaking of electricity which has been thus induced, we say it has been produced by induction; and so by an

induction coil we mean a machine by which a current of electricity in one wire or coil will induce a similar current in a second and separate coil. One may naturally ask what advantage is to be derived by doing this. The result of a preliminary experiment seems rather disheartening. We fit up two coils, connecting one to a battery, and we place the second coil near it, this coil

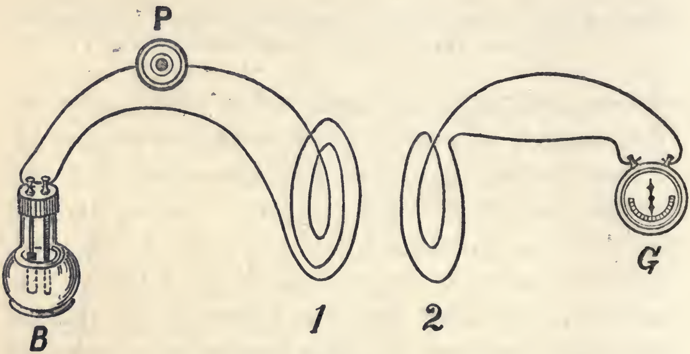


FIG. 10

THE PRINCIPLE OF INDUCTION COILS

When the push (P) is pressed a current flows through coil No. 1 from the battery (B), and at the making and breaking of this current an electric current is set up in coil No. 2, which is quite separate. This induced current is detected by the galvanometer (G).

being attached to an instrument for detecting the flow of a current. The diagram (Fig. 10) shows this simple arrangement with a bell-push inserted between the battery and No. 1 coil, so that we may conveniently switch off and on the current at will.

We know that as soon as we press the push a current will flow in No. 1 coil. We press the button, and watching the detecting instrument in the other coil, we see its

indicator fall to one side, showing that a current of electricity has been set up in No. 2 coil, and it is clear that this current must have been produced by induction from the battery current in No. 1 coil, as there is no connection between the two coils. Still keeping a finger on the push, we notice that the indicator has gone back to zero, showing that the current is no longer flowing in No. 2 coil, although the battery current is still flowing in No. 1. When we let go the push, we notice the indicator in No. 2 coil move once more, but this time in the opposite direction, and by repeating the experiment we find that every time we make or break the battery current in No. 1 coil a momentary current is set up in No. 2 coil.

There is the same amount of current set up at make as at break, but the latter takes place in a shorter time, and is therefore more intense, so to simplify matters we will leave the current produced at make out of account altogether. We need only remember that each time we press and let go the push in No. 1 coil a momentary current is set up in No. 2 coil. The quicker we press the push the more of these transient currents do we set up, and if we could make them follow very closely at each other's heels, they would make practically a continuous current.

We cannot hope to operate a bell-push rapidly enough to get this effect, and so automatic contact breakers are required. The induction coil may be made to do this itself, as will be explained. Or the make and break may be obtained by a small motor, driven by a separate battery. Part of the circuit may consist of a metal point dipping into mercury, and the motor may raise and lower the point alternately, producing the necessary make and break.

There are other methods, but first of all we wish to see what advantage an induction coil is going to give us.

We may imagine No. 1 coil sending out electromagnetic waves in the ether, and these waves, as they fall on coil No. 2, setting up a current in this coil. It is the changes in this field of influence which give rise to the induced current, for as long as the battery current keeps up a steady influence, no current is induced in No. 2 coil, but only when the waves are being set up or withdrawn does the current appear in the neighbouring coil. The more of these waves or lines of force we can entrap the better result we get, and we find the effect increased for every turn of wire we add to No. 2 coil, so we make this coil of very fine wire in order to get a great many turns into the field of influence. If we made the two coils exactly alike we should gain nothing, and even now we cannot hope to increase the amount of electricity, but we may alter its condition. We may think of the battery current in No. 1 coil as an easy-flowing current of considerable volume, while in No. 2 coil we have a small current at a very great pressure. It is difficult to find any convenient analogy, but I think one may liken the process to that of a mechanical lever. A workman wishes to move a large stone, but finds it too heavy. He gets a simple bar of iron, and putting one end under the stone, he places some obstacle under the bar or lever near to the large stone, and then applying his energy to the free end of the lever, he finds he can easily move the heavy stone. From whence did he get the increase of power? Energy cannot be created by a simple iron bar or by any other means, but it is apparent that the workman moved the

free end of the lever through a far greater distance than the stone was moved, so that he merely concentrated his energy. We might speak of the energy he put into several feet of movement being concentrated into several inches, and this may serve as a rough analogy of what an induction coil does: it cannot increase the energy, but it concentrates it, and we have a very high voltage or pressure, sometimes reaching over a million volts. A single battery cell gives a pressure of from one to two volts.

When the principle of an induction coil is once grasped, the construction is readily understood. No. 1 coil, which is the battery circuit, is called the primary coil or circuit, while the coil in which the current is to be induced is called the secondary circuit. The electro-magnetic effect of the primary coil is increased about thirty fold, by placing a piece of iron inside the coil. A bundle of iron wires is used, as they magnetise and demagnetise quicker than a solid piece of iron does. The battery or primary circuit is wound around this bundle of wires, the coil being, of course, carefully insulated, or otherwise the current will not go round and round the coil as is desired. One may always think of the insulation being to the current what a pipe is to water or gas. The two ends of this primary coil are connected to the battery, there being a contact breaker inserted between one end and the battery, as was represented in the diagram (Fig. 10) by the bell-push. The secondary coil of very fine wire is wound directly on the top of the primary coil, but very carefully insulated from it, and its two ends are left free, being merely finished off in convenient terminals, so that any desired piece of apparatus may be connected in circuit with this coil.

As already indicated, the contact breaker may be worked by the induction coil itself, for the bundle of iron wires, becoming a magnet whenever the battery current flows round them, may be made to attract a piece of iron attached to a spring, which, when attracted forward, breaks the path of the current from the battery.

Immediately the circuit is broken the bundle of iron wires lets go the spring piece, which, coming once more to its normal position, allows the current again to pass, whereupon the spring is again attracted forward, and so the make and break is kept up continuously. The motion is exactly that of the gong-stick in an ordinary electric bell, and it is the rapid to-and-fro movement of this spring that causes the monotonous hum in the air when an induction coil is at work.

The breaking of the battery circuit might be accomplished by turning a wheel round, having contact pieces at intervals on its periphery, and indeed this method was employed prior to the automatic arrangement just described. One modern method is to give a rapid motion to a contact lever by means of a small motor driven by electricity. There are also electrolytic contact breakers now in use, but the object of all is merely to obtain a rapid make and break of the battery circuit. The only other point to mention is that a condenser, made up of insulated layers of metal foil, is placed in the wooden base of the instrument, to act as a Leyden jar. The induction coil is also supplied with a switch, to turn off and on the battery current at will, and also a commutator switch, so that the direction of the current may be reversed.

If a glass tube, from which the air has been as effectively withdrawn as possible, be now coupled to the induction coil, a beautifully luminous effect is produced in the tube. This phenomenon has led up to some most important uses of the induction coil, which will be dealt with in the following chapter under the title of "Light that does not Affect the Eye."

CHAPTER XVII

LIGHT THAT DOES NOT AFFECT THE EYE

All light is of itself invisible—Early observations leading up to the discovery of the "X-rays"—How we are able to see the living skeleton—The means by which invisible rays are made visible—How the X-rays are produced—Some applications of the Röntgen rays.

THE title of this chapter may appear rather clumsy, but the expression "light visible and invisible," which is so much in use at present, has always seemed to me misleading. I remember how, when quite a youngster, I was very much impressed by the fact that all light must be invisible. Walking along one night in the dark I pictured the sun at the other side of this great globe, but sending his rays of light away out into space, reaching to the other planets. It was quite apparent then that light must be invisible, or we should see these rays of light beyond the shadow of the earth, and so I was impressed by the fact that all light is invisible before I came to learn the scientific explanation of the matter. As already pointed out, it is really a necessity that we should have a new word to denote light as an ether disturbance, so that it may not be confounded with light sensation in the material retina and optic nerve.

We have a great variety of ether waves, as explained

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SHANGHAI TELEPHONE EXCHANGE

In the Telephone Exchange at Shanghai the operators are Chinese boys, who have proved very efficient workers. The details of the switchboard are clearly seen, as described in Chapter XIV.

in a later chapter. Only a very small proportion of these waves affect our eyes. But while the retina is not disturbed by some rays of light, these affect the chemical preparation on a photographic plate. We are all now quite familiar with the so-called "shadowgraphs" produced by the Röntgen rays, or as Professor Röntgen named them "the X-rays," which reminds one of algebra, "let *x* be the unknown quantity." By the way, those who have examined such photographs carefully must have noticed that they are not merely shadows, but that there is a great variety of density, and that there is no flatness as in a shadow, but the objects are rounded off like solid bodies.

When in 1896 it was announced that the living skeleton could not only be photographed, but might be plainly seen upon a screen, and the movements of every bone watched, the whole civilised world was at once interested. There was a sort of fascinating eeriness about the subject which doubtless gave it a wider interest than scientific discoveries usually produce.

It will be of some interest to see how this very important discovery came about. There must have been a great number of observed facts leading up to this, for even the greatest scientists do not stumble across discoveries unless they are making their way along some definite path in which this previously unobserved phenomenon lies. The now famous German professor did not invent the Röntgen rays; they had been present in many experiments for a long time back, but had not been observed.

In the primitive electrical machines, in which the ether disturbance was produced by the experimenter holding his

hand against a revolving glass cylinder or globe, it had been noticed that if the air was withdrawn from the globe by means of an air-pump, a beautiful glow of light appeared inside the globe when it was excited by rubbing against the hand. This luminous effect was not present unless the globe was approximately a vacuum. This was known some one hundred and seventy years ago; and about that time it occurred to one experimenter to try if this luminous effect could be produced in the vacuum globe by electrifying it from another machine instead of exciting the globe directly by the hand. The Polish scientist who tried this was delighted to find that when he passed a charge of electricity from one of these primitive machines through a vacuum tube the luminous effect appeared, and he at once proposed to use this light in mines and places where an ordinary light was dangerous. If this method of lighting had been tried in any dangerous mine, I fear the consequences might have been serious, for it would have been very difficult to prevent sparks passing from the highly charged wires, and these sparks would be quite sufficient to cause ignition of gases followed by explosion. However, we find that for more than a century and a half this light produced by an electrical discharge in a vacuum has been known to scientists and to those interested in such matters.

When a discharge passes between two points in ordinary air, producing a spark, the air offers a great deal of resistance to the electricity, and the disturbance caused by the discharge is of quite a violent nature. The same, of course, holds good if the discharge takes place inside a tube filled with air; but if we connect the tube to an

air-pump and commence to withdraw the air, we soon find that there is not the same resistance to the electrical discharge, and that we are able to place the two points much farther apart and still get a discharge. As the air in the tube becomes less we find the discharge becoming quite silent, and instead of repeated sparks there is a constant stream of luminosity.

Even when we have got the very best vacuum that is possible, we must not imagine that there are no molecules of air left in the tube, for it can very easily be proved that the light is dependent upon some particles of air remaining. If the tube be filled with any other gas, such as hydrogen, and the pump made to withdraw all the gas it can, the discharge in the so-called vacuum remaining is quite different in appearance from that which took place after the ordinary air had been withdrawn from the tube. There is now a blue glow with a crimson effect in the centre, and if the tube has been filled with a mixture of gases before the pump is applied, the effect of an aurora borealis on a small scale may be produced.

It is therefore evident that the luminous effect is produced by the particles of air or gas left in the "vacuum," and we may imagine these remaining molecules to be bombarded about by the discharge so rapidly in the free space now at their disposal that they become luminous.

With improvements in air-pumps it was possible to produce more rarefied vacuums, and we are indebted to our great English chemist, Sir William Crookes, for much

progress in this branch of science. Crookes produced tubes with such high vacua that the diffused luminosity or glow concentrated itself into a direct stream between the two conducting points as though it were a luminous thread, and he found that a magnet held near the tube would deflect this stream from its direct path. It was also observed that, when these rays fell upon the glass of the tube, they made it glow with a green or bluish phosphorescence. These rays are now famous in the scientific world, and are called "cathode rays." Before these rays become observable, the air in the tube must be as greatly rarefied as it is away up about one hundred miles above the surface of the earth.

While Professor Röntgen, of Würzburg, was working with some of these high-vacuum tubes he found that there were other rays originating from the point where these cathode rays impinged upon the glass or upon any other obstruction. By further experiment he found that these unknown or X-rays would pass through a great many bodies which were quite opaque to ordinary light. Other substances were able to stop the rays, and when caused to fall on a photographic plate they set up the same chemical action as ordinary light, producing a negative in the usual way when developed. Röntgen thus showed that a photograph of the bones of the hand might be taken if the hand was interposed between the tube and the photographic plate.

We shall see in the following chapter the very great boon that this discovery has been to suffering man.

Crookes had already shown that if he caused the

cathode rays to fall upon different crystals, by placing them in the path of the cathode stream, the crystals became phosphorescent or fluorescent. It had also been observed that if a piece of glass, coloured greenish by uranium, were moved along in the spectrum produced by light passing through a prism, the glass reflected the colours as ordinary glass would do, but when moved along beyond the visible spectrum at the violet end the glass still showed the green tint, although there was no apparent light falling upon it. That is to say, there were light waves which did not directly affect the eye, but which were changed by striking upon the uranium glass and then became visible.

When the sun's rays pass through a glass prism the different wave lengths are separated and fall upon the floor or wall in a band of beautiful rainbow colouring, with the appearance of which we are all familiar. At one time it would have seemed ridiculous to suggest that there was anything more than the visible spectrum, but now we know that there are rays beyond this limit in both directions, although the eye does not detect them. Those beyond the violet end of the spectrum will affect a photographic plate, while some will even illuminate a fluorescent screen. In the other direction, beyond the red end of the spectrum, we find the rays or ether waves which affect the wireless telegraph receiver.

A fluorescent screen such as used in X-ray work is merely a cardboard coated with some fine crystals, such as platino-cyanide of barium. The ether waves striking upon these crystals are so altered that they are brought

within the scope of our vision. In other words, when the invisible X-rays fall upon the crystals they cause these to send out ether waves which do affect our eyes. The illumination of the screen lasts only so long as the X-rays continue to impinge upon the crystals. There are other *phosphorescent* substances which continue to emit light after the stimulating waves have been withdrawn.

When the X-rays fall upon a fluorescent screen they illuminate it evenly all over provided there is no obstacle between the tube and the screen to intercept the X-rays. If the hand be held between the tube and the screen, a shadowgraph or radiograph is produced upon the luminous screen.

The principle of the X-ray tube will be understood from the diagram on page 181. The cathode rays impinge upon the little sloping target, and this bombardment sets up the ether disturbance known as X-rays.

When we come to consider the nature of electric phenomena we shall see that the so-called cathode rays are composed of very small particles which cannot escape through the glass, whereas the X-rays, being merely an ether disturbance, can pass out through the glass of the tube. We are not sure of the nature of the X-rays, further than that they are a disturbance in the ether, possibly a series of splashes or thin pulses.

The value of the X-rays to us, as far as photography is concerned, is due to the fact that they can penetrate many substances which are opaque to light. The X-rays have little difficulty in passing through a wooden box. They penetrate the flesh of the hand with ease, but have their way blocked by the bones of the fingers.

There are other applications, such as the detection of imitation gems. A real diamond is quite transparent to the rays, while imitation ones are practically opaque. The X-rays have been used also in testing the manufacture of electric cables. By passing the cable between an X-ray tube and a fluorescent screen, the inside of the

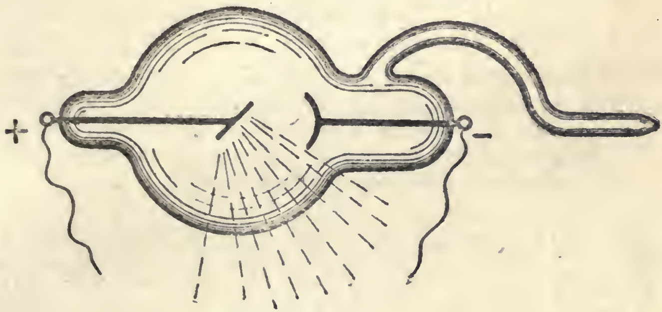


FIG. 11

AN X-RAY TUBE

This diagram represents a simple form of X-ray tube. The cathode rays pass from the cathode (−) to the anode (+). They are focussed by the saucer-shaped cathode so that they strike the target, which is seen lying at an angle. When the cathode rays are stopped suddenly by the target, they produce a sort of splash in the ether, as indicated by the dotted lines. This ether disturbance is what we call the X-rays.

cable insulation may be examined and faults located. The presence of foreign bodies in the insulating material is easily detected. The X-rays have also been of great value to the scientist, but their practical application in the medical world far surpasses any other application likely to be made.

CHAPTER XVIII

HOW ELECTRICITY PRODUCES LIGHT

The first idea of an electric light—Discovery of the electric arc—What happens in an arc-lamp—How we came to have incandescent lamps—The true meaning of combustion—Edison's first idea for a glow-lamp—A common error in comparing gas and electric lighting—An interesting old lady—Artificial daylight.

IT would be difficult to say when the very first thought of an electric light entered the mind of man, for such an idea might even have been suggested in some way to the philosophers of many ages ago. It is recorded that one ancient philosopher had observed sparks emitted by his stockings while in the act of undressing, and in these tiny sparks we see some connection between electricity and light.

Early experimenters must have been more impressed with this connection when the primitive frictional machines came into use, for in the dark some beautifully luminous effects were produced. It is not probable, however, that these distant workers ever dreamed of a practical electric light.

Early in the nineteenth century that very thoughtful Cornish experimenter, Sir Humphry Davy, made an important discovery. Having coupled together the whole

of his battery of two thousand cells, he connected a carbon pencil to each of the two battery wires, whereupon he found that if the carbons were made to touch each other, thus completing the circuit, and if then gradually separated, the spark between them became a very brilliant continuous arch or "arc" of light. Not only do the carbon points become white-hot, but a continuous stream of volatilised particles fills the intervening space. The carbons gradually waste away, but it will be understood that the heat and light are in no way dependent upon combustion. The arc is maintained by the electric current, which is necessarily at a high pressure to overcome the great resistance offered to its passage across between the carbon points.

The arc-lamp, with which we are all familiar in our streets, railway stations, or public buildings, is nothing more than a machine to feed the carbons forward as required, and to start or "strike" the arc. Unless the carbons are put in contact with each other to start with, the current cannot get across from the one to the other, but when the current is turned on the carbons are in contact with each other, and as soon as the current passes the lamp automatically separates the carbon points and thus forms the arc.

An arc-lamp placed in the focus of a large reflector in a lighthouse tower may be visible for at least twenty or thirty miles on a clear night, and indeed very powerful lamps equal to hundreds of thousands of candles may be discerned at a distance of over one hundred miles. Quite recently a flash-light has been put into St. Catherine's Lighthouse in the Isle of Wight, which is estimated at

fifteen million candle power, and which should be seen from the French coast in clear weather.

In connection with the arc-lamp it is interesting to note that no matter how close the carbon points are brought to each other at the outset no current will pass until they actually touch; then they quickly become heated, and when separated a bridge of carbon vapour is formed between them. If an arc-lamp "hisses" then one knows that the carbon points are not far enough separated, or if there is a flashing and spluttering the distance is too great, but an up-to-date arc-lamp works very steadily indeed.

An arc-lamp was used in 1858, when the foundations of Westminster Bridge across the Thames were being laid, but while this is sometimes quoted as the first time that an electric light was used for a practical purpose it is not really so, as the Parisians, some eleven years earlier, illuminated the Place de la Concorde by means of an arc-lamp.

In the arc-lamp it is, of course, necessary to replace the carbon-sticks or pencils continually, owing to their wasting away as already mentioned, but of late years many arc-lamps have been made in which the carbons are enclosed in a globe into which the air leaks but slowly, thus preventing the carbons wasting away so rapidly. While the carbons in an ordinary open arc do not last more than twelve to sixteen hours, an enclosed arc-lamp may burn for a hundred and fifty hours before requiring new carbons, which means a considerable saving, not only in carbons, but also in the work of attending to the lamps.

We have seen that Sir Humphry Davy was the first to

produce the electric arc giving us the basis of arc-lighting, and as the same ingenious experimenter showed that a continuous stick of carbon could be made white-hot by passing sufficient current through it, he has at least given the suggestion of another method of lighting. No doubt Davy's mind would be absorbed with the heating property of the arc, as that would appeal to him strongly, he being a great chemist, but this will be dealt with later in the chapter on "Electricity as a Heating Agent."

If a wire or thread of carbon is made white-hot by passing a current through it, the carbon will very soon disappear owing to combustion, and it was the prevention of this waste that made electric lighting by means of a carbon wire possible. Some people find it difficult to see quite clearly how it is that electric light has to take the fact of combustion into account and yet that it is in no way produced by combustion. I think this matter may be explained by a very simple and well-known experiment. If a lighted candle is placed inside a large glass bottle and its mouth closed, the candle burns for a little time, but its light soon becomes fainter and fainter and then disappears. A second lighted candle lowered into the bottle will now immediately go out. The reason for this result is no doubt plain to all. The bottle at the outset contained a certain amount of air dependent entirely upon its capacity, and when the lighted candle was put in the bottle was corked so that no air could escape or enter. No air has passed out of the bottle, and yet the candle will not burn. It is, therefore, evident that the condition of the air must now be quite different. There has been a chemical change going on: the carbon in the candle when

heated has been able to unite with the oxygen of the air, and has thus formed carbon dioxide, commonly called carbonic acid gas. The chemist signifies this by the symbol CO_2, which reads that a molecule of this new compound is composed of one part of carbon and two parts of oxygen. In chemistry each element has a distinctive and easily remembered symbol as C for carbon, O for oxygen, H for hydrogen, Cu for Copper, Zn for zinc, and so on. The chemical symbol for water will therefore be H_2O, a water molecule being a combination of two parts of hydrogen with one of oxygen.

To return to the bottle with the extinguished candle, it becomes apparent that the uniting of the carbon of the candle and the oxygen of the air has ceased, and as a good deal of the candle remains and can be relighted outside of the bottle, it is evident that all the oxygen of the bottle-full of air has united with the candle's carbon, so that no further chemical union can go on. To this act of chemical combination we give the simple name of "combustion," and in the case of the lighted candle, when we keep it well supplied with oxygen, as we do in burning it in the open air, the combustion will go on as long as there is any candle left. It is this combustion that causes the candle to give heat and light, for the minute particles of carbon become white-hot and luminous. We must have the combustion and consequent change of material to have the lighted candle, for if we prevent the combustion by taking away all the available oxygen, we, of course, get no chemical union, and, therefore, no light. But if we can raise and maintain a white heat by some other means than combustion then the conditions are quite different.

It was known from the outset that a current of electricity heated the conductor through which it was flowing, and the greater the resistance offered to the current the greater the heat. Sir Humphry Davy showed a wire of carbon raised to a white heat by the passage of an electric current, so all that remained to be done was to prevent any oxygen getting near the heated carbon. It is from the air that the carbon steals the oxygen, so our best plan is to keep the carbon out of the way of temptation by shutting it up where it cannot get a hold of any air. This is easily accomplished by sealing up the carbon in a glass globe after exhausting all the air from it by means of an air-pump. The carbon may now be raised to a white heat by the current and made to glow, but combustion is prohibited, and, therefore, there is no appreciable waste. Some tiny particles of carbon do manage to free themselves from the carbon "filament," as may be seen in a lamp that has been long in use, by a blackening of the inside of the globe.

These glow-lamps are descriptively named electric incandescent lamps. The carbon filament in one of these lamps is very fine, so that it offers a very poor passage to the current, and, therefore, is more easily heated, whereas the metal wires leading to the lamp and into the carbon are much better conductors, and allow the current so free a passage that the heating of them is quite inappreciable. The temperature of the little carbon filament is somewhere about 3,450° on Fahrenheit's scale.

Although Sir Humphry Davy's carbon stick became heated by the passage of the current, it did not at first seem possible to use carbon in any suitable form for

a small lamp, so the early experiments were all made with very fine metal wires of different alloys. The great difficulty, however, was that when a fine metal wire became white-hot and gave light it was very apt to fuse. One might picture this result as due to the molecules while clinging together by their natural cohesive force reaching such a rapid rate of vibration that they are no longer able to hold on to each other, and so the wire gives way, the metal tending to change into liquid form.

There is not this trouble with carbon, and after finding metals unreliable Edison made a suitable carbon wire by cutting thin slips of bamboo grass and charring them, while another practical filament was made by Swan by carbonising a linen fibre with sulphuric acid.*

The appearance of an ordinary glow-lamp is familiar to all, and while the filament looks quite substantial when the lamp is glowing, it will be found to be a very fine thread of carbon if examined while the current is not passing. This apparent difference in size is merely an optical illusion due to the intense light from the white-hot carbon impinging with considerable force upon the retina of the eye, and causing, as it were, a spreading of the sensation to more of the retina than the directly affected part, thus conveying the idea of a larger image. This effect is known as "irradiation," and may be observed

* In modern manufacture the materials for making the lamp filaments are dissolved into a solution having a consistency similar to that of treacle. This semi-liquid is then forced through small tubes, coming out as a continuous thread or wire, which is then placed on carbon moulds of any desired shape, and thereafter placed in a furnace and carbonised.

Photo.] [W. Stacey, Dunmow.

The Son of the Countess of Warwick in his little Electric Motor Car.

not only with brightly luminous objects, but even between black and white bodies. A very stout person looks stouter when dressed in white than when in black, and so on.

These glow-lamps have certain advantages over gas or other artificial illuminants, and not least of these is the fact that they do not steal any of the oxygen of the air, which we ourselves require to inhale in order to keep up the combustion in our bodies. Unless sufficient oxygen can, by means of our sponge-like lungs, be brought within reach of our vitiated blood with which it unites, we soon feel a difficulty in breathing and a lack of energy, which, as we are well aware, if carried to excess will mean a complete cessation of our vitality. Each ordinary gas light steals as much oxygen as several able-bodied men, so that it is very necessary to keep a room, which is illuminated by gas, well ventilated, and indeed we too often forget that we ourselves are incessantly demolishing the beneficial oxygen in the air of a room, and that it is, therefore, of much importance that at all times there should be a plentiful supply of fresh air.

The chemical products of a gas light soon tarnish and dirty the decorations of a room, so that the electric glow-lamp has a distinct advantage in this respect.

Without discussing the matter of comparative cost, it may be mentioned that some consumers having possibly read comparative statements of the cost per candle-power between gas and electricity are surprised to find their electric bill considerably higher than their former gas bill, but they will find the reason to be that they are using far more candle-power than they formerly did.

They would not be content to light a room electrically with the same candle-power as they previously used with gas, for the glow-lamp does not emit such a penetrating light, and if only the same candle-power were provided the room would appear to have a much poorer light.

In addition to the great convenience of electric light and the advantage of its leaving our life-sustaining oxygen alone, it is less heating, which for some purposes is an advantage. There is practically no risk of fire from glow-lamps if installed by expert workmen.

It may be noted in passing that in the electric arc-lamp the carbons, being exposed to the air, are subject to combustion, but this is merely an effect and not the cause of the light, as already explained.

I remember an old lady, who had been bed-ridden for some twenty years, having met with an accident at the age of seventy-two, but retaining clear mental faculties up to the time of her death at the age of ninety-two or ninety-three. It was most interesting to find what ideas this old lady had formed about this "electricity," which she had never seen at work, nor heard or read about further than from general remarks in the daily newspapers. She asked many interesting questions, and in connection with electric light, which she had never seen in any form, she wanted to know if the electricity burned in the lamp like gas or oil. It was quite a natural and a thoughtful question, and it is doubtful if a great many people, who are quite accustomed to the use of electric light, ever realise this point that while gas and oil are consumed in burning, in the sense of combustion as already indicated, it is quite different with electricity, as

it merely does its work and passes on. It is something like a river one sees guided to a waterwheel, and after turning the mill passing on its way as before to its great reservoir, the sea.

In the case of the river we know that the sun has evaporated some water from the ocean and deposited the vapour aloft in clouds, and that later the vapour has again liquefied and fallen upon the mountain tops, whence collecting together it gradually forms a river which, on its way back to the ocean, will do useful work in turning a waterwheel, etc. If we consider electricity as a disturbance of the ether ocean and the dynamo as a pump, then we have some sort of analogy, but as was already pointed out, it is impossible to find any adequate analogy for electrical matters.

We agree to speak of a current of electricity, not that we believe that there is a flow in the same sense as a stream of water, and while we find it convenient to think quite freely of the carbon filament of a lamp as offering so much resistance to the current that the carbon becomes heated and glows, we must not imagine anything akin to mechanical friction and resistance. We must express our ideas about electricity figuratively, and it is only if we forget that these expressions are arbitrary that any misunderstanding arises. Indeed, it was only when the early theories were formed, no matter how crude they may now seem to us, that advancement in matters electrical was made possible.

Electrical engineers have done much to cheapen the cost of producing electric current for lighting purposes. But within the last few years a great reduction in the

cost of electric light has been accomplished by means of glow lamps made upon a different plan. Instead of employing a filament of carbon, very fine filaments of rare metals have been used. In one class of lamps, of which the *osram* is well known, the metal is *tungsten.*

The filaments of these lamps are made of the rare metals whose names they bear. The metals are produced from their compounds in the form of fine metallic powder, which is then mixed with a suitable binding paste, and squirted through small apertures to form the fine filaments. These are placed in a mixture of gases, and an electric current is passed through the filaments, causing the ingredients of the binding material to combine with the gases, while the particles of the rare metal become welded together.

These metallic filaments become white-hot very much more easily than the carbon filaments. Some of the metallic-filament lamps now in use take less than one-third of the electric current required for a carbon-filament lamp of the same candle-power. This is a great step in advance, and places electric light in a very much stronger position. If we can continue making strides of this kind, electric light will soon have no rival.

CHAPTER XIX

ELECTRICITY FROM MECHANICAL MOTION

A powerful substitute for batteries—How a dynamo works—Alternating currents—An analogy—Whence the magnets get their current—Advantages of alternating currents.

SIR HUMPHRY DAVY used a battery of two thousand cells to produce his historic electric arc, and all the early electric lamps were worked in a similar manner by batteries. As the upkeep of a battery means the renewal of the zinc plates, etc., and a great deal of attention when a large battery is used, it is quite clear that electric lighting would never have come into general use unless some better substitute had been found to replace the expensive and troublesome battery.

The finding of a suitable substitute was arrived at in this way. Our great British scientist, the late Michael Faraday, found that if a loop of wire were moved up and down between the poles of a magnet there was a current of electricity set up in the wire. Faraday pictured a magnetic field between the poles of the magnet, and his imagination filled this space with "lines of force," and he said it was when the coil or loop of wire passed through

these imaginary lines that a current was originated. It was quite evident that it was only as long as he kept the coil moving up and down in the magnetic field that the current was present in the wire.

The next step was to mount a coil of wire on a spindle and revolve it in the space between the poles of a magnet, and, as was anticipated, the effect was greatly enhanced, because the coil could be made to pass through the imaginary lines of force much oftener. The little magneto-electric machines sometimes used for medical purposes, but perhaps oftener for amusement by dealing out electric shocks, are simply arrangements by which, when one turns a handle on the outside of the box, a coil is made to spin round in the neighbourhood of a magnet.

It then occurred to people to make such machines on a very much larger scale, and to use steam-engines to drive the coils round at a great speed. Such contrivances were called dynamo-electric machines, which name we have discarded, merely using the word "dynamo" (Gr. *dynamis*, force).

In the small experimental machines at first constructed ordinary steel magnets were used, but in order to get a stronger magnetic field these were soon replaced by electro-magnets. A dynamo now consists of a coil or coils of wire mounted on a shaft or spindle, this part being called the armature, and driven round at a high speed between the poles of an electro-magnet.

It is all very well to know that there is an electric current set up in the revolving coil, but how are we to get the current away from the continually moving coil? We

cannot, of course, have wires directly attached to the coil, as they would be twisted and broken off as soon as the coil began to spin round. We can, however, keep in touch with the revolving coil by a very simple arrangement, as shown in the diagram (Fig. 12). A single rect-

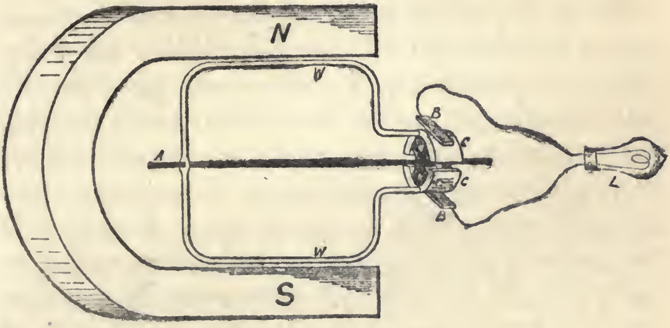


FIG. 12

PRINCIPLE OF A CONTINUOUS-CURRENT DYNAMO

N and S = North and south poles of magnet.
W W = Rectangular loop or coil of wire.
A = Spindle for above to revolve upon.
W and A together are called the armature.
C = Two bent metal contact pieces to which the two ends of W are fixed.
B B = Brushes which rub against the revolving contact pieces and make connection to the main circuit.
L = A lamp in the main circuit.

angular loop of the wire is here shown with the two ends attached to two pieces of metal, which have been bent round the end of the spindle, but insulated from it and from each other; these we will call the contact pieces. Two flat pieces of metal, marked B, and called brushes,

although they perhaps look more like combs, press against the contact pieces on the shaft. On looking at the diagram, it is now clear that the current has a path out from the loop by the top brush through the wire attached, which may lead to a lamp and back by the lower brush to the coil, thus completing the circuit.

When the coil or loop revolves, the brushes will, of course, keep in touch with the coil, but they will change partners as regards contact pieces at each half-revolution. This changing of partners is very convenient, for when the coil in its revolutions enters the magnetic field in front of the north pole of the magnet, the current flows in one direction, while on leaving that part of the field the current set up is in the opposite direction, so what we really have in the coil as it spins round is a current pulsating first in one direction and then in the other, at every half-revolution.

Again, looking at the diagram, it is clear that if the current is passing out from the loop or coil by the top contact piece, the brush touching it will conduct the current away to the main circuit, in which are placed the lamps, etc., while the current returns by the lower brush. Let us follow the lower contact piece only. As it leaves the lower brush the current in the coil changes in direction, so that by the time it reaches the top brush the current, instead of entering the coil by this contact piece, is now leaving by it. When the other contact piece was in the same position it was also the exit for the current, and so we find that whichever contact piece is uppermost it is the exit for the current in the coil, and in this way the brush fixed at the

top is always leading out the current. We therefore have a current flowing in one direction through the outer circuit.

If we had two different objects, one hot and the other cold, and if we imagine these two bodies changing alternately from hot to cold, one always being hot while the other was cold, we could place the left hand on the hot object and the right hand on the cold object, and then changing the position of the hands just as the bodies changed temperature, we could always have the left hand on the object that was hot, and the right hand on the cold object. If this were possible in practice we should have a continuous flow of heat through the body from the left hand to the right. In similar fashion we have a continuous flow of electricity from the one brush to the other, the brushes standing stationary, and the changing contact pieces moving from one brush to the other. It is a simple case of two negatives making a positive.

Instead of consisting of flat pieces of metal, the brushes are usually made of little blocks of carbon carried in a suitable holder, and these give a splendid rubbing contact with the armature's contact pieces. Instead of there being only two contact pieces, as in the diagram, a large armature is built up of a number of separate coils, each coil having two contact pieces, arranged so that the brushes simultaneously touch the two ends of one coil, then the two ends of the coil following it, and so on. Instead of having only one electro-magnet surrounding the revolving coil, it is now common to have several magnets arranged to act together, so that the

coil passes the poles of each magnet in rotation, but the general principle is represented in the simple diagram (Fig. 12).

Remembering that in the revolving coil there is really a quickly pulsating current, first in one direction and then in the other, let us try and get at this current directly without converting it to a continuous current. If we take away the two contact pieces, shown in the diagram, and place two complete rings alongside of each other on the shaft, insulating them from each other and from the shaft, we may now fasten one end of the coil to each of these ring contact pieces. If we then place the top brush in contact with one ring and the lower brush against the other ring, it is clear that each brush will always remain in contact with its own ring, and there will be no interchanging of partners, as was the case with the first arrangement. Consequently there will be no reversal of the current coming from the coil, so we shall have a pulsating current in the outer mains just as we have in the revolving coil itself. Such a pulsating current, first in one direction and then in the other, is called an alternate or alternating current, and a dynamo arranged with these complete rings is called an alternator or an alternating dynamo. The arrangement of contact pieces and brushes on a continuous-current dynamo is termed the commutator, as it commutes or changes the current. For diagram of alternator see page 202.

Before leaving these dynamos to see what we can do with them, there is an interesting point to note. Where is the large electro-magnet to get electricity from to produce its magnetism? We simply steal some of the

current that the dynamo is generating and pass it round the magnet. That is all very well when we once have the currents coming from the dynamo, but how are we to get it started? When a dynamo has once been used the iron of the magnet always retains a trace of magnetism, sufficient to set up a very weak field. When the coil revolves very rapidly in this a correspondingly weak current is produced, which goes to augment the magnet and so on till very quickly the dynamo is in full working order. When a dynamo is constructed there is usually sufficient magnetism in the iron itself to set up a weak field at the very outset, but if not it could easily be momentarily coupled to the electric supply mains.

It is very convenient to be able to feed the magnet with the current which it is itself producing, but we can only do this with a continuous-current dynamo. The current going round the magnet must be all in one direction, and so where the electricity is being led away from the dynamo as an alternating current it will not do to pass this round the magnet. To work an alternating dynamo we therefore require to have a separate exciter, which consists of a small continuous-current dynamo, or, if there be a number of alternating dynamos working in one station, it is more convenient to run one continuous dynamo to feed all the magnets.

It might seem very inconvenient to have a pulsating current continually changing its direction in the circuit, but while at first this class of dynamo was left severely alone it has of recent years come well to the front. Before considering the advantages which have brought

this dynamo into a prominent position to-day, let us see what takes place in a circuit in which an alternating current is at work.

If a small glow-lamp be put in the circuit leading from an alternating dynamo, arranged as just described, and if the alternations of the current be slow, there will, of course, be a great unsteadiness in the light, as the current will practically cease at the moment of change from one direction to the other. If, however, the armature coil is driven round at a very high speed, the current may be made to change its direction as often as fifty times in one second. With such rapid alternations the light will be perfectly steady as far as we are able to detect it with our eyes, for at each fiftieth part of a second we have a light thrown upon the retinas of our eyes, and as the image of a bright light will not fade away for about one-tenth of a second each of the fifty pulsations in the lamp will overlap its predecessor, and we may imagine our eyes receiving, as it were, a perfectly continuous cinematograph impression of a quickly pulsating light.

Even at this speed of fifty alternations in one second, there is bound to be a sudden rise and fall in the current at each pulsation, although not visible to the eye. For some purposes even this would be detrimental, but this further difficulty is overcome by winding two separate coils on the one armature and arranging them so that when the current is at its turning point in the one coil it will be at its maximum in the second coil, or better still, if three separate coils and pairs of brushes be used the defect can be further reduced.

We can imagine an alternating current as a wave

swinging to and fro, and this we call its phase, so that when two coils are used and there is, as it were, two separate waves overlapping each other, this is called a two-phase current, or we may speak of a machine with three coils as a three-phase alternating dynamo.

When describing the principle of the arc-lamp, it was noted that particles of carbon broke away from the point of the carbon pencil at which the current enters the arc, and it is therefore obvious that this carbon will waste away very much quicker than its neighbour, in point of fact, about twice as quickly. If we now use an alternating current, the current will be first entering at one pencil and then at the other, so that both will waste away equally, which is a considerable advantage in favour of an alternating dynamo as far as arc-lighting is concerned.

Another advantage, which has been recognised in these alternators, is that we can conveniently obtain a much higher voltage or pressure, which makes the distribution of current over a long distance much easier, and the alternating current is very simply changed from a high voltage to a lower one, or *vice versâ*.

Of course the alternating current is of no use for some purposes, as, for instance, electro-plating, in which process a steady current is required to carry the metal over from the plating material to the article being plated. However, an alternating current may be made to drive a motor, which in turn drives a continuous-current dynamo, and in this way a current of the one class may be altered to a current of the other class at very little loss.

In speaking of these dynamos, I have only mentioned

a fixed magnetic field and a rotating armature in which the current is induced, but it is, of course, as easy to have these two reversed, and so we have some dynamos in which the electro-magnets form the moving part, the coils in which the current is induced being stationary.

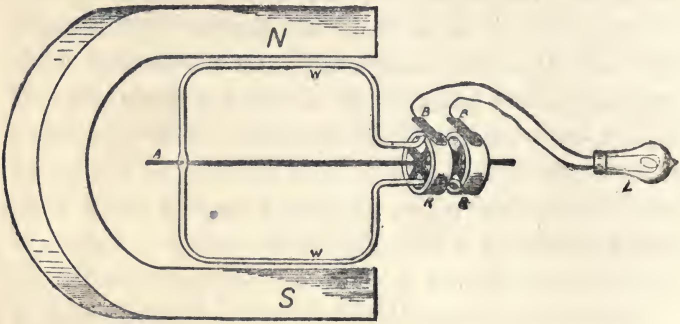


Fig. 13

PRINCIPLE OF A DYNAMO SUPPLYING ALTERNATING CURRENT

N and S = North and south poles of magnet.
WW = Rectangular loop or coil of wire.
A = Spindle for above to revolve upon.
W and A together are called the armature.
(When revolved in the magnetic field an electric current is produced in the coil WW, the current changing its direction at each half revolution.)
RR = Two metal rings; one fixed to each end of coil WW.
BB = Brushes which press against the revolving rings and thus make connection between the revolving coil and the outer or main circuit.
L = A lamp in the main circuit.
(The current in the main circuit will, of course, alternate in direction just as in the revolving coil.)

CHAPTER XX

MECHANICAL MOTION FROM ELECTRICITY

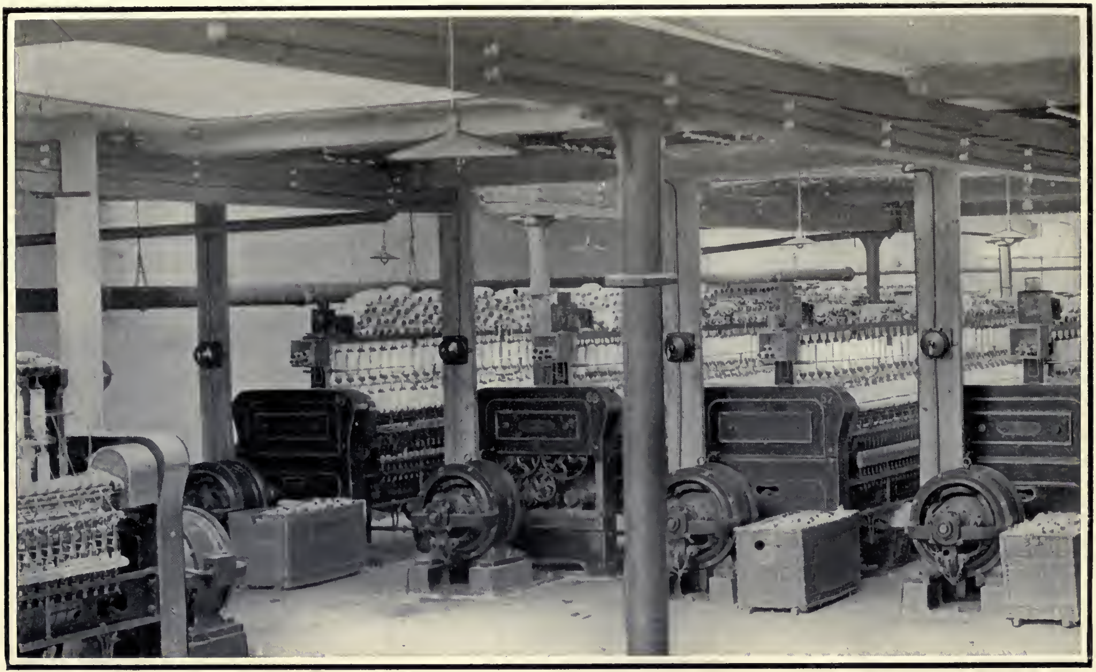
A mysterious machine—How electricity makes the motor go—An explanatory experiment—A dynamo may be a motor—The source of the motion—A lecturer's amusing experience—An early idea—A motor requires a dynamo—A great advantage—Gigantic power carried by a dormant wire—Present clumsy methods—A coming revolution.

WHEN one goes into an engine-room and looks at an engine at work there is—to many—a peculiar fascination about the machine, though not because of any mystery, for we are all familiar with the expansive power of steam which gives the impelling force to the piston; but when one watches the armature of an electric motor spinning quietly round at a high speed, one does feel a sense of mystery, and it is not surprising to find that the electric motor is a source of wonderment to the majority of people.

Of all the subjects connected with electricity, I have found that the outsider seems particularly interested to learn how electricity can drive machinery, and make a train or car to go. Whether it has been a deputation of artisans from the city with a request for a lecture, or a conversation with an intelligent farmer in a country

district, the one question which seems to be uppermost is just, "How does electricity make the motor go?" If we are content to know how it is done, to the same extent as most people understand how a steam-engine works, then there is no difficulty.

In explaining the principle of the steam-engine one might point to a kettle of boiling water on the fire, the lid of which was being repeatedly lifted by the expanding steam. To explain the electric motor I would point to a little magnetic needle being attracted by a magnet brought near to it, and say that that is the way electricity makes the motor go. It is simply a case of magnetic attractions and repulsions. I take the little magnetic needle pivoted on its stand, and having painted the north pole red so that it may be easily distinguished, I bring a steel bar-magnet near to it. I first of all hold the south pole of the bar-magnet towards the north pole of the needle, and the needle at once swings round towards it, but when it comes round to the bar-magnet I quickly turn the latter round in my hand, thus pointing its north pole towards the needle. This pole now repels the north pole of the needle, causing it to continue on its circular path, and with a little practice I soon find I can set the little magnetic needle spinning round on its centre. This is just the principle of what happens in a motor. Instead of a little magnet balanced on a pivot, there is a coil of wire mounted on a spindle, and in an early chapter we saw that a coil of wire, having a current of electricity flowing in it, was in every respect a magnet. In place of the bar-magnet which I held in my hand, there is a large



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Spinning Machines driven by Electric Motors. Instead of conveying steam power by long shafting and innumerable leather belts, stationary wires are connected to the small motors seen on each machine.

electro-magnet, the poles of which surround the coil-magnet mounted on its spindle. It will not be convenient to keep changing the poles of this huge magnet as I did with the bar-magnet, but if we let this magnet remain constant, and we change the direction of the current in the coil-magnet at each half-revolution instead, the result will be the same. It will be remembered that when we pass a current of electricity through a coil in one direction, the one face of coil becomes a north pole and the other a south pole; but when we reverse the current, sending it through the coil in the opposite direction, then the north and south poles change places.

It is apparent that this motor, which we have now built up in our imaginations, is simply a dynamo: a large electro-magnet with an armature or coil between its poles. But we are going to do just the reverse of what we did with the dynamo. We caused the armature of the dynamo to be driven round at a great speed, and we led away a current of electricity from the revolving coil. We had a rapidly changing or alternating current in the coil, but by means of the commutator and brushes we led the current out in one direction into the mains. In the case of the motor, we are now going to lead the same kind of current back to the brushes, taking the current from another dynamo, and as soon as the current enters the armature-coil its poles will be attracted by the poles of the large electro-magnet surrounding it, and it has been so placed that this attractive pull will cause it to turn round on its spindle half a revolution. At this point the armature coil will have its ends in touch with

the opposite brushes from which it started, and so the current is reversed in the armature, causing it again to turn a half-revolution. It is now back to the position it started from, and so sets off once more, the current reversing at every half-revolution. In this way it soon gathers speed; the quicker it goes, the oftener will it reverse its points of contact with the brushes, so the revolving coil really becomes a magnet, changing its poles at an almost incredible speed. Referring again to the simple explanatory experiment from which we set out, it is just as though I held the bar-magnet steady, having a separate bar-magnet stationed with its opposite pole at the other side of the magnetic needle, or it might be simpler to think of a large horseshoe magnet with its legs spread out to allow the magnetic needle to spin round on its centre between the poles. Thus having a steady magnetic field or influence, it is necessary that the magnetic needle, when turning into the position to which it is attracted by the magnet, should then reverse its poles and receive a further attraction to make it continue on its journey. Of course it is impossible to have a permanent magnetic needle changing its poles continually to suit our convenience, but the magnet formed by a simple coil of wire, carrying a current, will behave in this manner, and so electric-motors are not only possible, but thoroughly efficient and powerful engines.

A boy holding a magnet near to the magnetic needle of a small pocket or pendant compass can make the needle move round, by carefully reversing the position of

the poles of his magnet he may make the magnetic needle spin round; it is the same power which makes the motor go.

By applying mechanical motion to a dynamo, in revolving its armature, we get electricity, and by giving the same machine electricity, its armature revolves and we get mechanical motion. In the latter case we call the dynamo a motor. Of course, in actual practice there are differences of detail in construction depending upon whether the machine is to be used as a dynamo or as a motor.

When one becomes accustomed to the idea that a coil of wire carrying an electric current is a real magnet, then there is no difficulty in understanding the principle of electric motors, but I trust that the foregoing explanation will not meet with the same fate as did one explanation of this matter given in a lecture I heard recently. The lecturer had been requested by the chairman, a bailie in the town in which the lecture was being delivered, to explain how electricity made the cars go. The lecturer explained the matter in his own way, and he no doubt was somewhat surprised and amused when the worthy bailie, in proposing a vote of thanks, said that the lecture had been most interesting, but for the life of him he could not see yet what it was that made the cars go.

When speaking of a dynamo and a motor being exactly the converse of each other in action, it is interesting to note that if two electro-static machines, such as those described in an early chapter, be connected together by

wires, so that the high-tension charge, generated by the one machine when rotated, is led to the collectors of the second glass or vulcanite plate machine, the latter will begin to rotate also, its plates being attracted round by the charge on its collectors. The reversibility of the dynamo and motor should not really appeal to us as anything strange, for we have the same converse actions in everyday life, as, for instance, when a windmill is driven by the wind, thereby producing mechanical motion, while on the other hand we may apply mechanical motion to a windmill or fan, driving it round and producing a wind, as is demonstrated by a ventilating fan.

In the early days of electricity the distinguished American professor, Joseph Henry, constructed an electric motor on quite a different principle from that which we have been considering. Imagine a pair of beam scales with two iron pans, and at a little distance underneath each an electro-magnet. If an electric current be sent first to one magnet and then to the other, and so on alternately, the beam of the scales will be made to rock or see-saw, just as one sees in an old beam engine. The up-and-down motion of the beam turns a crank which drives the fly-wheel round. This early electro-motor was arranged to automatically switch the current from one magnet to the other at each stroke, but the principle of the machine entailed a very great waste of power. Of course, the machine was not made in the form of a pair of scales, but the principle was just as described.

Whenever we see an electric motor at work, whether in a workshop or factory driving machinery, or on a tram-

way car propelling it along, we may be quite sure that there is, possibly at some considerable distance, a dynamo being driven round by an engine, and also that there must be a wire or cable carrying the electric current from the dynamo to the motor. Of course, it is possible to drive a motor by means of a powerful storage battery, as is often done, but not economically.

One might ask what is the use of first driving a dynamo by an engine and then making the dynamo drive a motor. It is clear that we cannot get as much power from the motor as we get from the engine itself, for there must be some waste of power in friction, etc., both in the dynamo and the motor. There is certainly nothing to be gained in this direction, but the actual loss in power is surprisingly small, the motor giving about ninety horse-power for every hundred horse-power of the engine.

The dynamo and motor are, however, of very great advantage, because they give us a most convenient means of conveying power to a distance. We can have a powerful engine with a dynamo fixed at some convenient place, and from this station we can distribute power to anyone requiring it. We can convey the current to a wire stretched along a roadway or public street, and thus allow the motor underneath a moving tramway car to keep in touch with the distant dynamo.

Before the days of electrical transmission of power it was often very difficult to drive machinery in different parts of a works without fitting up various engines in different places. It is interesting to note in some of the

older factories how our grandfathers had to arrange long belt drives or long connecting shafts from one building to another to convey power. If some engineer, a generation ahead of his time, had come along and said that he could save them all this trouble, for a fixed and stationary wire could carry the necessary power to any desired distance, I have no doubt our grandfathers would have counted him a knave, or would possibly have advised his friends to take better care of him. To-day there seems little to marvel at in this possibility of carrying power along a simple wire, for we have become quite familiar with such facts in everyday life. How convenient to be able to carry power by fixed wires to a ventilating fan on the wall or roof of a building, far away from any source of power. What a saving is made in being able to take a drill or other tool to any part of a ship's hull, or to some out-of-the-way portion of a bridge under construction, using wires to carry the power from the distant generator to the tool.

At present we convey great train-loads of coal from our coalfields across the country to our manufacturing centres. One sometimes sees heavy train-loads of coal passing each other in opposite directions, one lot leaving a town and another lot entering it. Then we have to cart the coal about from one place to another, and all this carrying means a great expenditure of energy. I think one might safely prophesy that some future generation will marvel that we were content with such clumsy methods. It would be possible to convert all the coal into electrical power at the pit-head, and from there

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A PORTABLE ELECTRIC DRILL

If a piece of work cannot be taken into the engineering shop, the shop can practically be taken to the work. What a contrast between the smart work of an electric drill, as shown above at work on the stern of a steamer, and the many weary hours of hand labour at one time necessary!

distribute it for motive, lighting, or heating purposes to all the surrounding towns.

Where no coalfields exist within a hundred-mile radius, the coal could be carried to immense generating stations, supplying a great many towns covering a large area. Already there are indications of things moving in this direction.

Sir J. J. Thomson has taken a much longer look ahead in his address to the British Association at Winnipeg in 1909. Referring to the enormous quantity of energy lavished upon this planet by the sun, he pointed out that, according to the measurements of Langley, when the sun was high and the sky clear the heat energy received was equivalent to seven thousand horse-power per acre. Following this up, Sir J. J. Thomson said: "Though our engineers have not yet discovered how to utilise this enormous supply of power, they will, I have not the slightest doubt, ultimately succeed in doing so; and when coal is exhausted and our water power inadequate, it may be that this is the source from which we shall derive the energy necessary for the world's work. When that comes about, our centres of industrial activity may perhaps be transferred to the burning deserts of the Sahara, and the value of land determined by its suitability for the reception of traps to catch sunbeams."

CHAPTER XXI

ELECTRIC RAILWAYS, NIAGARA, ETC.

The astonished Chinaman—The distant source of energy—Power stations—How the power reaches the car—Where the danger lies—Electric railways—The "live rail"—Higher speeds will be demanded—Mono-rail system—Electric motor-cars—Canal haulage—Electric launches—Niagara Falls—How the power is distributed—Latest developments at Niagara.

WHEN the man in the street sees an electric tramway car for the first time he thinks it peculiarly mysterious, even although he may be aware that there is an electric motor fixed below the car driving its wheels round. He does not have the same feeling about a horse-drawn car or a puffing engine, for the source of energy in these cases is very apparent. A cable haulage car does not even call forth surprise, as he knows of the endless rope, continually travelling along in an underground channel, to which the driver may attach his car and let go at will. The man in the street is more learned than the Chinaman of whom Sir Oliver Lodge tells the story, that when he first saw a cable-car in the streets of Chicago he regarded it for some time with open-mouthed astonishment, and then exclaimed, "No pushee—no pullee—go like mad!" That the ordinary man, however, does puzzle over the electric car is demonstrated by a conversation reported to have been overheard

in London between two Irish labourers. In discussing the principle of electric tramways, one of the men explained that it was "that sort of fishing-rod on the top that makes the business go." He evidently supposed that the trolley pole was pushing the car along in some mysterious way. It is really because the source of energy is not apparent that an electric car has a mysterious appearance. The motor-man merely turns a switch and, no matter how heavily the tram is laden, off it goes.

Whenever we see anything in motion we know there must be an expenditure of energy going on. The car is expending a great deal of energy, and we know there must be a corresponding amount of energy being generated behind the scenes. The car may be miles from the source, but at the distant generating station there is much activity. The stokers are at work looking after the boilers, although their work is greatly lightened by the modern mechanical appliances, which feed forward the coal, weigh it, and then shoot it into the furnace. When we stand and look along a great row of furnaces and boilers at a generating station, and when we think of the tremendous expansive power of steam, we understand the source of energy for the cars. Close to the boiler-house we find the engine-room, where we see several huge engines at work, each engine being equivalent to four or five thousand horse-power. Here we see enough mechanical motion to drive all the cars in the town. But how is this power to be conveyed to the cars? Each engine is directly coupled to a large dynamo, and from these dynamos wires or cables conduct the electricity along the car routes. If the town be a large one it is

general to have one central station, where all the boilers and engines are placed, and where all the necessary current is generated. To transmit this power economically to a distance it is necessary to have the current at a very high pressure. From this station the high voltage current is led away to a number of different sub-stations placed at convenient points on the various car routes. The large cables carrying this highly dangerous current, which is probably about 6,500 volts, are well buried under the ground.

In these sub-stations this high-pressure, alternating current, received from the generating station, is first of all transformed or "stepped down" to the low pressure of a few hundred volts. To accomplish this transformation there is no moving machinery. The current merely passes through a stationary coil of wire and induces another current in a neighbouring coil, the change of voltage or pressure being obtained by there being a different number of turns of wire in the two coils. These coils are called static-transformers, and their principle is the same as that of the induction coils explained in a former chapter. There is no need of a making and breaking of contact, as the current itself, being an alternating one, is starting in one direction and then in the other alternately, producing the constantly changing field of influence required to set up a current in the neighbouring coil.

The very high pressure current, reaching the substation by these underground cables, has now been transformed to a low pressure, but it is still an alternating or to-and-fro current, whereas it is usually preferred to send a continuous or uni-directional current for driving the

motors on the cars. This further transformation is easily effected, for we have only to use this current to drive an alternating motor, to which we couple a continuous-current dynamo, from the brushes of which we may now lead away a convenient current for the tramway motors. This sub-station has not generated any of the power, it has merely altered the condition of the current to suit requirements, and the loss of power in doing so is surprisingly small. This final current is then led out by underground cables, from these dynamos, along the car routes. At intervals along the route, where one sees a large metal box at the side of the road, the current is fed on to the overhead trolley wire. The trolley pole, which is attached to the roof of the car, keeps in touch with this bare trolley wire, and the current passes down a wire from this pole to the switch-box beside the motor-man. He may pass the current direct to the motor under his car, in which case it goes off at full speed, or he may pass the current through a number of different resistances, only allowing a certain amount of current to get to the motor. By moving his controlling switch he thus throws more or less of these resistances, or coils of wire, into the circuit, and he is thereby able to regulate the speed of his motor. After passing through the motor the current is led by way of the axles and wheels of the car to the rails. It is then led off by cables at short intervals and thus conducted back to the power-house.

Instead of carrying the trolley wire overhead, it may be placed in a channel under the track, with an open slot through which a connecting rod may pass, the appearance of the track being the same as for cable haulage, but this

underground trolley wire is naturally a much more expensive system to install. There is really very little danger from the overhead wires, as they are well looked after, being constantly examined and kept in good repair. The chief source of danger is in telephone wires falling, but guard wires are put up right along the track, immediately over the trolley wire, to prevent the telephone wires getting in contact with the "live" wire. No doubt when the Government take over the telephones in this country the overhead network of telephone wires, existing in some large cities, will entirely disappear, being placed underground, so that this source of danger may be removed very soon.

Already horse-drawn tramway cars seem quite out of date, although London has not yet dispensed with all these "antiquated" vehicles. These are, however, fast disappearing, and even in quite small towns one finds a modern system of electric cars. It is almost as certain that the steam locomotive will be banished from the railway tracks. How convenient for a railway locomotive to receive its energy "ready made," by simply keeping in touch with a stationary wire or rail. If desired there need not be any separate locomotive, for the passenger car may carry the electric motor itself, just as the tramway car does. Electric railways have been built on the Continent with overhead trolley wires, but engineers in this country have preferred a third rail, placed near the ground, to act as the conductor of the current. It is this rail which is called the "live rail," and which at the first caused considerable alarm. As electric traction becomes more common, people will learn to keep clear of live rails, just as one would avoid a red-hot poker. If this "live

rail" danger will only scare trespassers off the railway tracks altogether it may be the means of preventing much loss of life annually.

It is not probable that the travelling public of future generations will be contented with a railway speed averaging about fifty miles per hour. At present the business man in London may want to see about some business in Glasgow, but he cannot afford to spend sixteen hours in getting there and back. While steam locomotives sometimes attain a speed of eighty miles per hour for a few miles, the best average, over a run of from thirty to fifty miles, is about seventy miles per hour in America, and about sixty miles in Great Britain.

Already engineers are turning to electricity to attain higher speeds, and the rate of the expresses of the future would, no doubt, seem to us at present highly excessive, if not impossible. Already a speed of one hundred and thirty miles per hour has been attained on trial lines in Germany, while one Russian engineer suggests a scheme whereby he proposes to take passengers from St. Petersburg to Moscow, a distance of six hundred miles, in three hours' time, which means an average of two hundred miles per hour, or more than three miles every minute.

An electric railway of a novel character was shown at the Brussels Exhibition in 1897, where a train was mounted on a single rail, supported on tressels, the rail standing about four feet off the ground. The railway cars were arranged like the packs on a mule's back, part of the car hanging down on either side of the central rail, in stride-leg fashion. A guide-rail ran along on both sides of the tressels to keep the car steady. The train

was driven electrically, and attained a speed of ninety miles per hour, but there is nothing to prevent the speed being greatly increased. This method of building a railway is called the mono-rail system. We have already seen the electrification of several important suburban railways, and that this subject is one to be reckoned with in the near future is evident from the large amount of space now devoted to it in all electrical journals.

It is clear that a motor placed on a train or tramway car can be kept in touch with the distant generating station, but not so with motor-cars intended to run free on the public roads. In this case it is necessary for the motor-car to carry its own source of power about with it. This is a distinct disadvantage. Not only does it necessitate the independent motor-car carrying heavy storage batteries or accumulators, but these will require to be constantly recharged with electricity. For this reason electric motor-cars, or electro-mobiles, are only convenient where a number of generating stations are within easy reach, as in large cities. In this case they are a distinct improvement, as they move along in a much less impulsive manner than does the impatient petrol car. They are also entirely free from rapid vibration and smell, and they are very easily controlled, as is clearly demonstrated in one of the illustrations in which a boy of eight years of age is seen driving his own electric motor-car. If it were possible to construct an accumulator of very large electrical capacity, and yet weighing only a mere fraction of present storage batteries, the inventor would undoubtedly make a very great fortune.

The subject of electric haulage for canals has attracted

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An Electric Tractor used on the Charleroi and Brussels Canal. The electric motor of the tractor receives current from the overhead wires, which are connected to a dynamo at the distant generating station. The tractor runs on the ordinary tow-path, and draws the boats through the canal.

a good deal of attention both in America and on the continent of Europe. There are several means of applying electricity for this purpose. The canal boat may be supplied with an electric motor on board, coupled to an ordinary propeller, and the necessary current led to the boat by a trolley wire and pole in the same manner as is done with an electric tramway worked on the overhead system. This, however, is not always convenient, and it has been found that the wash, caused by the boat propelling itself, is very detrimental to the banks of the canal.

A second plan is to have an electric tractor, or motor-car, on the ordinary tow-path, the power being got from overhead wires. This system is at work in Belgium, and is represented in one of the illustrations, but it has been found expensive owing to heavy upkeep.

The third plan is a modification of the second one, and consists of an electric locomotive running on rails along the tow-path, the motor getting its current by means of a trolley pole and overhead wire. This plan is at work in the United States on the Erie Canal, and it is found that one of these electric locomotives can draw from three to six canal boats at a speed of from four to six miles per hour, and this is done electrically at a smaller cost than by mules giving a speed of one and a half miles per hour.

For many years electric launches have been used as pleasure-boats on the River Thames and elsewhere. The power is derived from accumulators placed under the seats, and these work an electric motor, to which the propeller is coupled direct. The speed of the launch

is conveniently regulated by means of a switch, in the same manner as already described for a tramway car. These boats glide along very gracefully, being free from any smoke, heat, escaping steam, or incessant vibration, but they are, of course, dependent upon some neighbouring generating station to have their accumulators recharged. Some boats carry sufficient power to take them about forty miles without a change of accumulators, and this distance they will cover in seven or eight hours, going at a speed of from five to six miles per hour. With the advance of petrol motors on board small boats, the electric launches will occupy a similar position towards these that electro-mobiles do as compared with petrol motor cars.

Returning to the generation of electric power, we find some further points of interest. Before we can get electricity from the dynamo we must apply considerable power in revolving its armature. It does not require much force to spin an armature round on its bearings, but when the current is once set up in the coil of the armature it then becomes a powerful magnet, and is attracted by the surrounding magnet in the opposite direction to which we are rotating it, and to overcome this magnetic attraction a force of many thousand horsepower is required, if the dynamo be a large one. As long as we can supply sufficient power to drive the dynamo, it does not matter, of course, whether it be supplied by an engine, a water-wheel, or a windmill. Water power in great quantities is not very general, but quite a lot of waterfalls on the continent of Europe and a few on this island are now harnessed. The great centre

of interest in this respect, however, is in America, where they seem always to do things on a big scale. If we only had a Niagara Falls at hand in the centre of our island we should want no other source of energy.

Even the great flowing river of Niagara enabled the early settlers along its banks to drive machinery for sawing timber, etc., but it is only during the last few years that the harnessing of some of its vast power has been undertaken on a large scale. Many generations ago mechanical engineers must have looked on this great source of energy with envy, and wished that it were possible to convey this power away to distant places of industry. Electricity makes this dream a reality. Instead of causing the flowing river to turn an ordinary water-wheel, some of the water is run off into a tunnel, measuring about twenty feet square. The river is about a mile in breadth at this point, it has travelled twenty miles from the great Lake Erie, and after making a sudden leap over a precipice of one hundred and sixty feet, forming the great Niagara Falls, it makes its way to Lake Ontario. Niagara practically drains the great lakes of the interior, which have a total surface area of nearly one hundred thousand square miles. Some idea of the immense volume of water may be gained when we attempt to picture eighteen million cubic feet of water passing over the precipice in every minute of every day. This represents a power of nine million horse-power, of which about five and a half millions are available for use. The total power of the works already constructed and in course of construction will amount to less than three-quarters of one million, and yet this is a gigantic power.

The water for the great Power Station is got by tapping the river about one and a half miles above the falls. The tunnel, already referred to, is cut with a gradient of thirty-six feet in the mile, till it has fallen to a depth of about two hundred feet, of which about one hundred and forty feet are available for use. A number of deep pits are dug from the surface, each about one hundred and sixty feet in depth, and these pits communicate with the water tunnel. At the bottom of each pit is placed a large water turbine of five thousand horse-power, mounted on a vertical or upright shaft, which extends right up to the surface, where a dynamo is fixed to its top end. We have the turbine or propeller away down at the bottom of the pit being rapidly revolved by the rushing water in the tunnel, and on the top end of the shaft we see the moving part of the dynamo being rapidly spun round and generating the electric current. This means a considerable weight on the foundation of the long upright shaft, but the pressure of the water below is ingeniously contrived to relieve this.

The recent extension for utilising the falls on the Canadian side of the river will develop about three hundred and seventy-five thousand horse-power, which is about half of the grand total already referred to. The Canadian Power Station will distribute electricity to Toronto, which is about seventy-five miles distant. The current will leave the Power Station at the immense pressure of sixty thousand volts, and after reaching Toronto it will, of course, be reduced to working voltages. One power station on the continent of Europe has for many years successfully distributed power over a greater dis-

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Niagara Falls Power Station. A rushing stream of water from Niagara River, taken some distance above the Falls, is conducted down a very steep underground tunnel and passes beneath the Power Station shown above. The dyramos are fixed at the top end of an upright shaft, 160 ft. long, whilst at the bottom end is a turbine propelled by the rush of water in the tunnel.

tance—machinery in Frankfort being driven from a generating station at Lauffen, which is one hundred miles distant.

The great Power Station at Niagara has caused quite a crowd of industries to spring up around it. There are grain mills, timber works, paper mills, iron works, engine works, and electrical industries of every description, all receiving power from the great falls. Large electric furnaces are also erected for producing aluminium from bauxite, and there is no doubt that ere long the electro-chemical industries will receive a great impetus, and what are at present only possibilities will, by means of this great supply of electricity, become active realities.

When a Select Committee of the House of Lords passed the third reading of the Durham (County) Electric Supply Bill, it was mentioned that the waste heat from the coke ovens in the blast-furnaces was being used for the production of electricity, and that the companies promoting the Bill had been supplying power at "actually less than the power supplied at Niagara."

CHAPTER XXII

ELECTRICITY IN THE OBSERVATORY

Visit to an observatory—How the velocity of the wind is recorded—Continuous record of wind's direction—Electricity notes time to one thousandth of a second—Far distant earthquakes record themselves in Great Britain—How the apparatus works—A missing link in meteorology.

CLIMBING the hill on which the observatory is situated the visitor has no difficulty in finding the building, as it is conspicuous with its large rounded dome, which serves as a revolving roof for the large telescope. At the side of the building one notices a very tall pole on the top of which a little windmill is spinning round. If the visit be made on a fresh spring day, when a stiff breeze is blowing, one finds the little windmill very busy, while on a quiet summer day it may be practically at a standstill. It is clear that the faster the wind blows past the windmill the quicker it will revolve, and it has been so arranged that one kilometre of wind passing will cause the little windmill to turn round one thousand times. If we can tell how many thousand revolutions the windmill has made in one hour, we know how many kilometres of wind have passed in that time. As a kilometre is a little more than half a mile (about six-tenths) we know that if there have been eight thousand

revolutions in an hour then five miles of wind have passed, and so we speak of there having been a wind of five miles per hour.

Of course, no one is going to attempt to count the thousands of revolutions performed by the windmill in an hour: it is here that electricity comes to the observer's aid. Two wires lead down from the lofty windmill to the recording instrument placed inside the observatory, so that the outdoor apparatus can send signals down to the indoor recorder. The little windmill drives a train of wheels, so geared that the last little wheel makes only one revolution for every thousand of the windmill, and as this little wheel makes an electrical contact, which is equivalent to pressing a bell-push, at the end of each of its complete revolutions, the recording instrument receives a signal which indicates one thousand revolutions of the windmill, or in other words, the passing of about one half-mile of wind. If the recorder receives fifty signals in one hour, then the speed of the wind is roughly twenty-five miles per hour. Each signal or impulse received causes an electro-magnet to move a pen one upward step across a paper carried on a cylinder or drum which makes one complete revolution in twenty-four hours. The paper is marked off in hours, so that it can easily be seen at a glance how many upward moves the pen has made in any hour, and as each step represents one kilometre of wind, the speed of the wind is readily calculated from the French measure to English miles.

A storm will record a speed of fifty miles per hour, or may even rise as high as eighty miles, and I have known the little windmill to spin round to the tune of ninety

miles per hour, but with a further increase of the gale the little servant deserted his lofty post, and was returned the following day to the observatory in several pieces, having been found in different quarters of the town. By such means a continuous record is taken of the velocity of the wind, day and night. Such instruments are called anemometers, from the Greek word *anemos*, signifying wind, and *metron*, measure.

A record is also taken electrically of the direction of the wind. A little vane on the top of the pole points in the direction from which the wind is blowing, and it carries on it a spur or finger which lightly touches a number of little metal studs placed in a circle underneath it. There are sixteen of these metal studs or contact pieces, from each of which a wire runs down to the observatory. These represent the sixteen cardinal points of the compass, North, N.N.E., N.E., E.N.E., East, and so on. The duty of the vane is to telegraph down to a recording instrument on whichever of these wires it is standing over. If the wind be due north, then the finger of the vane rests on the end of the wire arranged to represent north.

Inside the observatory the other ends of these sixteen wires are fixed in the recording apparatus. At the end of every minute a little finger or feeler is made to sweep across these sixteen wire-ends, and the moment it touches the end of the particular wire with which the vane is in contact outside the circuit is completed, the current from a battery finds a path to an electro-magnet, which in turn operates a pen. This pen is not normally in contact with the paper, but when the magnet receives an impulse

it draws the pen sharply against the cylinder, and as the pen is carried across the paper along with the feeler, the pen is made to mark at the moment the feeler touches the wire upon which the outdoor vane is standing. The paper is, of course, ruled off to represent N., N.N.E., etc. It is just as though the vane were supplied with sixteen different bell-pushes, each representing a particular point of the compass, and at the end of each minute it pressed the button that the wind caused it to point to. By the method described a continuous record is taken of the direction of the wind at the end of every minute right throughout the day and night.

Climbing up the stairs in the tower of the observatory till he reaches the dome, the visitor finds, during the night, the astronomer observing some phenomenon in connection with one of the planets. The observer sits there looking through a huge telescope, which he calls his equatorial instrument. It points to the opened slot of the dome, and the whole telescope is being very slowly revolved by clockwork in the opposite direction to that in which the earth is turning, so that the instrument remains pointing at the heavenly body. The visitor notices two wires leading to the clockwork, and he is informed that the speed of this motor-clock is electrically controlled by the beat of the standard clock, situated downstairs in the observatory.

The observer requires to read the position of his telescope by means of a graduated scale marked around the axis of the instrument. The degrees are so minutely marked off, and at such a distance from him, that it is necessary to read them through a microscope fixed to the

side of the telescope. All is dark in the dome, and yet the observer must have a light to read this scale by. A very tiny electric lamp makes a useful little assistant here, for when placed close to the scale at the objective of the microscope, it illuminates the scale beautifully, and sheds no detracting light in the dome.

Yet another pair of wires attract the visitor's attention, and these are leading to something which the astronomer holds in his hand. It is a contact maker, which is the equivalent of an ordinary bell-push, and from this a pair of wires lead down into the observatory, where a chronograph or time recorder is at work. The astronomer wishes to record exactly when a certain phenomenon occurs, so keeping his eye to the telescope, he has merely to press the button of the push, which he holds in his hand, and the chronograph downstairs will note the exact time to within one thousandth of a second. Before going downstairs to see this chronograph, which is so called from the Greek words *chronos*, time, and *grapho*, I write, the visitor remarks that he is surprised to find that the dome requires to be moved round by hand to keep the open slot opposite the telescope. Having electricity at hand, it would be a simple matter to apply a little motor to the wheels of the dome, and the motor could either be under the direct control of the observer or it might at times be automatically controlled by the clock driving the telescope round.

Coming down to the chronograph the visitor finds it a rather clumsy affair after the small and compact wind-recording instruments. There is a large cylinder carrying a sheet of paper wrapped around it. The cylinder is

slowly revolving by clockwork, its speed being electrically controlled from the standard clock. A pen moves slowly along the length of the cylinder, its motion being exactly like that of the tympanum and stylus of a phonograph, so that if the moving pen were left in contact with the revolving paper it would mark a spiral round and round the cylinder from one end to the other. The pen is normally not in contact with the paper, but at the end of each second of time the pen is made to strike against the paper, making a small dot. The pen is drawn sharply against the paper by an electro-magnet, which receives an impulse from the standard clock at the end of each second. Thus the chronograph paper shows a continuous series of equi-distant dots on the paper, the space between any two dots representing one second. The push in the observer's hand, away up in the dome, is connected by wires to the electro-magnet of the pen, so that he can also send an impulse and make the pen strike the paper at any desired moment, independent of the regular motion given to the pen by the clock. Thus a mark will be made in between the two dots representing a second. By means of a scale the position of this dot may be measured, and the time of the phenomenon be correctly found to the one-thousandth part of a second. The astronomer has wires led to his transit telescope and to any other parts of the observatory from which he may desire to record the exact time of various phenomena.

To obtain an absolutely accurate fraction of a second it is necessary to take the "personal equation" into account, for some small fraction of time must elapse between the moment the observer sees a star cross the

spider's-web line in his transit telescope and the instant at which he presses the button of his push to make the signal to the chronograph. Some observers' nerves and muscles will act quicker than will others, and so the personal equation of any observer is determined by experiment.

One astronomical friend tells me that with long practice he is able to split a second up into ten equal parts. Getting the beat of the standard clock in his ear, he can observe correctly to the tenth part of a second, so that the chronograph is only indispensable when a more exact fraction is required, or when the observer is working at a point beyond earshot of his standard clock. The chronograph has also a wide field of usefulness in timing the speed of projectiles, etc.

On reaching another part of the observatory, the visitor is somewhat surprised to learn that earthquakes occurring in all quarters of the world are made to leave their record by means of a small instrument in this room. Such instruments are called seismographs, from the Greek words *seismos*, an earthquake, and *graph*, I write. In order to prevent these being disturbed by any local earth vibrations, such as caused by trains passing in the neighbourhood, etc., a deep pit is dug about twenty feet down into the earth, then a solid masonry pier is built up, and the seismograph rests on the top of this pier. In this way the instrument is really resting upon the solid earth some twenty feet down, and is quite free from any surface disturbance.

There are two seismographs, one for recording far-distant earthquakes, and the other only replying to local

ones. The latter instrument looks the much more imposing of the two, in its large glass case forming a cube of about six feet. In the centre of the case is a large circular glass plate, which has been smoked to give it a good black surface upon which a pen point may scratch a line. There are three different pens resting on its surface at different parts. Each of these is connected to a different piece of metal, so hung on a stand that it will move with the slightest change of level. One weight is so arranged that it will move with any motion from north to south, another records any motion from east to west, while the third metal weight is hung on spiral springs, so that any vertical or up-and-down motion will be recorded.

The glass plate upon which these pens are to move to and fro will, of course, require to revolve in order to take a record of the movements. It would not be convenient to keep the plate continually revolving, as local earthquakes are fortunately few and far between in this tranquil little island of ours, and so it is necessary that the plate be set in motion on the occurrence of an earthquake. It is here that electricity comes to the aid of the seismologist. The clock for driving the glass plate is left fully wound up, but a catch locking into one of the wheels prevents the clock from going, so that the plate remains stationary. This little catch may be drawn out of position by a small electro-magnet, so that anyone could start the clock by pressing the button of a bell-push connected to a battery in circuit. However, it is not the intention of any person to wait on indefinitely to set the apparatus in motion at the required time;

this must be done automatically by the earthquake itself. In place of the ordinary bell-push, in which one wire is pressed against another to complete the circuit, there is a different arrangement here. The one wire is fastened to a little piece of metal in which a tiny hole is drilled, and the other wire hangs down freely in the centre of this hole, but does not touch the surrounding metal. This wire is attached to the bob of a little pendulum, which will move with the slightest change of level, thus bringing the wire in contact with the metal attached to the other wire. The first tremor of an approaching earthquake is sufficient to bring about this contact, which is the equivalent of pressing the button of the push.

It is very important to be able to tell the exact hour at which any earthquake did occur, and so another clock with an ordinary time dial is left wound up, but held at twelve o'clock by a catch. This catch is released by the same current that starts the driving clock, and so the time clock begins to go at the first sign of an earthquake, and as the clock sets off from twelve o'clock the observer coming to the apparatus later can tell exactly when the earthquake occurred. This clock is placed close to the glass plate, and is provided with a little pen, which makes a small mark on the edge of the revolving plate at the end of each second, so that the observer can tell the exact time of any particular movement indicated by the traced lines on the plate. I have seen a very good record taken by one of these seismographs in Scotland of an earthquake occurring at a distance of two hundred miles.

The instrument which records earthquakes happening

at the other ends of the earth is not electrical, and so I will merely mention it in passing. It consists of a very light aluminium boom delicately poised in a horizontal position, so that it will swing from right to left by the slightest change of level of the pier on which the apparatus stands. On the outer end of the boom there is a thin aluminium plate or shutter, having a longitudinal slit in it, while the wooden case enclosing the apparatus has a lateral slit, so arranged that the light of a lamp falling through these two slits forms a spot of light on the centre of a paper ribbon which is slowly moving along by clockwork. This paper is photographic, so that it takes an impression of the spot of light, and if the boom carrying the shutter remains perfectly stationary the light will mark a straight line up the centre of the passing paper. Any movement of the boom to right or left will move the pencil of light to one side or the other, and in this way the very smallest earth movements are recorded.

I have seen excellent records, taken in Scotland, of the deplorable earthquakes that have occurred in Siberia and the more recent ones in India, in each of which many thousands of lives were lost. I have been rather surprised to hear some men, well learned in science, suggesting that these seismographs would serve no useful purpose; but may we not hope that these records are the beginning of a line of research which may ultimately enable men to predict seismological disturbances and warn the inhabitants to flee from a threatened area?

Many theories have been formed of the cause of earthquakes; none seem to appeal to one's mind as very satisfactory; but these seismographs will doubtless aid in

arriving at an understanding of the true nature of these great natural disturbances in this planet of ours.

Man has already acquired considerable knowledge in the prediction of storms, of wind, and rain, and yet one does not feel enough confidence in "weather reports" to decide emphatically whether to take an umbrella or a walking-stick on one's daily wanderings. Of course one difficulty is that there is a great variety of weather in different parts of the island at one time, but there is a factor which doubtless takes part in the changes of weather, and which I do not think appeals forcibly enough to the meteorologist. There is a continual changing of the electrical condition of the atmosphere, and this must have some connection with other atmospheric changes.

Lord Kelvin invented an apparatus for recording these changes, but no very definite work seems to have been done with it. The apparatus requires a good deal of attention, and I have seen one of these instruments go idle for months for lack of time to attend to it.

There exists a very delicate instrument called a quadrant electrometer, which measures the amount of charge of any electrified body. The principle is to compare the charge with a known standard charge, and the standard is got from a battery of a hundred small primary cells. The atmospheric charge is obtained by placing a large copper bucket of water out of doors on an insulated stand. If water is allowed to continually drop from the bucket, the latter will become charged to the same potential as the surrounding atmosphere. An insulated wire leads the charge indoors to the electrometer, where its effect is compared with that of the standard charge. The varia-

tion of effect gives movement to a small mirror which, by means of a pencil of light, traces its movements upon a photographic paper, and in this way a rise and fall of electrical potential is recorded.*

* The Coats Observatory at Paisley (Scotland) contains practically all the apparatus described in this chapter. This splendidly equipped observatory was presented to the town by some of the Thread magnates, whose name it bears.

CHAPTER XXIII

ELECTRICITY AND THE PHYSICIAN

Early exaggerated notions regarding the electric shock—An electric "cure" in the fourth century—Modern quackery—Some ways in which electricity aids the physician—A much-dreaded disease at last overcome—Examining the inside of a patient—An eccentric heart—Other organs distinguishable—An old lady and a lost needle—X-rays on the battlefield—The necessity for the apparatus to be in qualified hands.

AS soon as primitive electrical machines had been constructed, early in the eighteenth century, it became apparent that electricity had quite a startling effect upon the human body. At first the electric shock caused great alarm, as its magnitude had been grossly exaggerated by the few experimenters who had experienced it. One distinguished Dutch scientist declared he would not take a second shock for the crown of France, while on the other hand another experimenter announced that he was willing to die by electric shock in the interests of science. Another experimenter's wife after receiving two shocks was said to be rendered so weak that she could not walk, and though her husband had also suffered great convulsions, she tried a third shock, which was so violent as to cause bleeding of the nose; and so the exaggerated reports went on. As these early electrical machines became less rare, it soon became known that the shocks from

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X RAY PHOTOGRAPHS.

The Feet of the Mummy of an Egyptian Princess, some 8,000 years old. The whole of the left and part of the right foot are shewn.

The Hand of Lord Hugh Cecil.

them were really not so dreadful as they had been pictured.

The idea of electricity being used for medical purposes seems to be very old indeed, as a writer living in the fourth century of the Christian era declares that "a freedman of Tiberius was cured of the gout by a shock from a torpedo fish." I have no doubt the cure was as genuine as the many professed to have been obtained in recent times by wearing magnetic lockets, rings, or belts, or by using "electric hair brushes," all of which must be placed under the category of quackery. There is no doubt that hypochondriacal invalids might receive, through their own imaginative powers, more "nerve," and in this way it has been possible for quacks to display genuine testimonials.

These early quackeries, no doubt, made people somewhat doubtful of the genuine attempts to use electricity as a curative power. It was found that the activity of muscles, nerves, and other tissues could be stimulated by electric currents, and some rash people at once declared that electricity was life itself. Even to-day one sees in quack advertisements such statements as "Electricity is Life." It was claimed by one experimenter that living germs had been actually formed in water by electricity, but when the matter was investigated it was proved that the germs were associated with some impurities in the water, and when the experiment was repeated with distilled water, there was absolutely no result.

Electricity is employed by the physician as an aid to diagnosis in cases of paralysis, etc., but its most important use lies in the art of healing. Until recently one of its

chief applications was the stimulating of muscles into action, by which they might be kept exercised and prevented from degenerating during a temporary breakdown of communications between the muscle and the central nervous system.

With the recently acquired knowledge of the existence of "invisible" rays and ether waves of different kinds there was opened up quite a new field of work. It was found that some waves destroyed the life of bacteria or retarded their growth, and in this connection may be mentioned the Finsen light treatment.

A Finsen lamp may consist of an ordinary arc-lamp, the rays from which are reflected to the diseased part, being passed through a lens of water on their way in order to obstruct the heat waves. The beneficial rays are not the ordinary light waves, but those beyond the visible spectrum, termed ultra-violet light. These ultra-violet rays are not only present in the arc-light, they are plentiful in sunlight, but the atmosphere readily absorbs them to such an extent that the arc-light is richer in these.

We are all familiar with the dreaded disease "tuberculosis," which when affecting certain of the internal organs, and in particular the lungs, we call consumption, and which, when appearing externally, attacking the skin and underlying tissues, is known as "lupus." We are all too familiar with its unpleasant appearance when it attacks the nose, mouth, or cheek of the patient, but it is not necessarily confined to the face. These tubercular diseases of the skin have long baffled the physician, although they have been shown to be due to specific

organisms, but now the bacteria* have succumbed to these searching rays. Curiously enough these same rays are most hurtful in cases of small-pox, and aggravate the disease very considerably. In the case of lupus these rays not only kill off the bacteria, but stimulate the tissue, and thus aid very materially in the patient's rapid recovery. The affected part has usually to be exposed to the rays very frequently for some months, and while a great number of cases can be pronounced complete cures, there are others that seem too far advanced to be overcome.

The X-rays have been found to operate in a similar manner in cases of lupus, malignant ulcers, etc., and sometimes the two treatments are used alternately.

In some cases of even twenty years' standing, which had been treated by all other methods, including the surgeon's knife, only to return again, these searching rays have completely annihilated the disease. The results obtained are really marvellous, and more especially so as the majority of the cases coming for treatment are those for whom there seems no further hope of cure by other methods.

In addition to the Finsen light and X-ray methods there is to be added the use of high-frequency currents, such as are obtained from large Wimshurst machines, or more recently by an arrangement of induction coils and Leyden jars. Sometimes one method is found to act

* While bacteria are termed organisms, it must be understood that they belong to the vegetable kingdom, just as fungi do. Some people seem to think of these microbes, not only as having animal life, but as possessing a kind of intelligence, or instinct, by which they may make their way about from one place to another.

better than another in particular cases, and a change of treatment is found with many patients beneficial. Again one method is sometimes more easily applied than another owing to the position of the diseased part, but it has been established beyond doubt that each of these methods is curative.

Electricity gives the surgeon a most convenient method of cauterising by heating a fine platinum wire on passing a current of electricity through it, and it also provides him with tiny lamps by means of which the cavities of the body may be examined.

Apart from the curative properties of electricity, the possibility of being able to examine the "inside" of a patient is of primary importance. A patient is brought in with a fractured arm or leg, and the surgeon can at once see what injury has been done to the bones. The spinal column and ribs can be examined, but the rays do more than distinguish the skeleton, although it is in connection with the bones that the Röntgen rays are at present of chief service. With properly adjusted tubes the heart's action may be examined, and it gives one at first quite an eerie feeling to see a friend's heart at work.

In some of our large hospitals it is a daily occurrence to have to fish coins and other foreign bodies from the throats of children. The little patient is placed between the X-ray tube and a fluorescent screen, and in a moment the coin is detected. An exact description of its position is noted and handed to the surgeon, who can fish it out easily with his "coin-catcher."

By means of the X-rays and a fluorescent screen other

organs of the body are quite distinguishable, such as the lungs and the liver, and it is curious to watch the movement of the separating diaphragm at each long breath drawn by the lungs.

If a needle or any other foreign body be accidentally lodged in the flesh, it can at once be located and got out without unnecessary cutting. The other day a medical man showed me an X-ray photograph he had just taken of the arm of an old lady, who had met with an accident. The photograph proved that no injury had been done to the bone, but it incidentally showed a needle embedded in the arm close to the wrist, and probably carried about unconsciously for a lifetime. As the lady was over seventy years of age, and as there was no likelihood of the needle troubling her now, the matter was not mentioned to her.

A specialist finding a boy's throat giving him trouble discovered, by means of the X-rays, a halfpenny embedded in the throat tissue, the coin having evidently been there for some considerable time.

It is difficult to estimate the great value of an X-ray apparatus on the battlefield for finding out at once where the bullets or fragments of shell have lodged without the painful and unsatisfactory probing formerly necessary. One can remember how even the best skill failed in the case of President Garfield, of the United States, who was shot in 1881 by a disappointed office-seeker. Had the existence of these X-rays been then known there is little doubt that the President would not have had to depart this life at the age of fifty.

It is impossible to tell not only how much suffering has

been avoided but how many lives have already been saved by the aid of Röntgen's discovery. The use of the X-rays in taking photographs, or more particularly for curative purposes, should not be attempted except under experienced medical supervision, as too long exposure or the use of a defective tube may bring about serious "burns," which in some cases have become permanent sores. Reports of such occurrences should not, however, deter any patient from submitting himself or herself to the rays under the guidance of a competent physician.

CHAPTER XXIV

ELECTRICITY AND RADIUM

Exaggerated notions of radium—Radium detected by electricity—How radium was discovered—Why it costs so much—How all bodies, if sufficiently cold, become phosphorescent—Radium and "shadowgraphs"—The physician and radium—The atom slowly breaking up—May we ever hope to transmute the baser metals into gold?—How we might realise what a million really is—How very minute quantities of radium are traced—Is the old problem of perpetual motion at last solved?—Radium is continually producing electricity—How radium remains at a higher temperature than its surroundings—Is all matter radio-active?

WHEN the wonderful properties of that magic-worker radium were made known to the world its capabilities soon became greatly exaggerated and distorted in the mind of the general public. Its rays were to do far greater wonders in the hands of the physician than those dealt with in the last chapter, and it was claimed that even cancer would flee on exposure to the radium rays.

Some predicted that radium would be in the near future a great source of motive power and of heat, enabling us to dispense with the clumsier methods of the present time.

The announcement of the properties of radium did not come as such a surprise to those interested in science, for other radio-active bodies were already well known,

although not nearly so active, yet even among scientists there were those who feared that the properties exhibited by radium would upset some long-established theories, such as the conservation of energy. It did not take long, however, for the first excitement to subside.

In order to justify the coupling of radium and electricity together in the title of this chapter, I may remark at the outset that but for electricity it is doubtful if the presence of radium could ever have been detected, as will be explained later, and before the close of the chapter there will be shown a very intimate connection between radium and electricity.

It is interesting to trace how radium came to be discovered. For a very long time it had been known that certain substances, such as zinc sulphide, would phosphoresce in the dark for some considerable time after being exposed to light; and the general public have been long familiar with luminous paints as used on match-boxes, etc.; uranium salts were supposed to belong to the same category; but shortly after Röntgen had discovered that his X-rays could affect a photographic plate, Professor Becquerel, of Paris, found that uranium emitted rays in the same way; and I remember seeing one of the earliest "shadowgraphs" produced by exposure to uranium, about 1896. These rays were named "Becquerel rays," after the discoverer. It was soon found that uranium did not require to be previously exposed to light in order to give out these rays, but continued to be incessantly radio-active.

A little later Sir William Crookes, of London, found that the radio-activity was not really due so much to the

uranium itself as to some "impurity" in the salts. It was then that Madame Curie, wife of Professor Curie, of Paris (herself a distinguished chemist), set about a long series of chemical experiments to try and locate the most radio-active element. Her husband soon joined her in the painstaking search, and they found that the "tailings" or residue of the ore from which uranium had been extracted proved to be more radio-active than the uranium itself. They then set about separating one constituent after another by chemical processes (evaporation, crystallisation, precipitation, etc.), and they ultimately found three distinct elements showing radio-activity. These the Curies named radium, polonium, and actinium, each of which is highly radio-active, but while polonium appears to be most active, radium occurs in the greatest quantity.

The metal radium has never been separated, but is found in combination with chlorine as radium chloride, or with bromine as radium bromide. The total amount of these radio-active bodies found in pitchblende, from which they are extracted, is, according to Professor J. J. Thomson, less than the gold held in solution in sea-water.

As it would be necessary to treat thousands of tons of pitchblende to obtain one pound of radium, it will be readily understood wherein the great cost of radium occurs. Of course the quantities even of the compounds that have been extracted are exceedingly small; and, indeed, we cannot hope that there will ever be any great accumulation of radium, as it is only matter in a transitory state, probably being a disintegrated product of

uranium, and during its own existence being itself busy breaking up into other forms of matter. Of course it takes a very long time to disappear, but its production is probably very much slower.

Radium chloride looks very much like ordinary table-salt, with a slightly yellowish colour. One of its most striking properties is the power of some of its rays to cause certain chemically prepared screens to fluoresce, just as a Röntgen-ray apparatus does, but on a much smaller scale. Radium chloride and bromide form crystals which are self-luminous in the dark, but the "scintillations" seen in a Crookes spinthariscope are due to the incessant bombardment of the invisible rays against a small fluorescent screen.

It may incidentally be remarked here that the difference between fluorescence and phosphorescence is that the former is only present as long as the exciting rays are falling upon the crystals, whereas a phosphorescent body emits light for some considerable time after exposure. Professor Dewar maintains that all bodies would become phosphorescent if their temperature was lowered sufficiently, and he has produced phosphorescence in egg-shells, ivory, feathers, and paper when cooled down to about 200° below zero (Fahrenheit scale) by means of liquid air, the temperature of which is another hundred degrees lower still. When these bodies are at such a low temperature and exposed to light, they seem to have the property of absorbing energy and then giving off light at higher temperatures.

Another property of radium is its effect upon a photographic plate, by which shadowgraphs or radiographs may

be produced; but as these had already been produced by X-rays this property did not cause so much wonderment.

The next property of interest to the public is the physiological effects of some of the radium rays, which cause a sore on any part of the body kept for long in proximity to even the minute specimens at present existing, and these effects are not immediately apparent, but develop some days after exposure. Great hopes were at first entertained that in the medical world radium would prove of great value, but it seems doubtful if there is any different effect from that already obtainable from electrical apparatus. When good specimens are more easily obtained it may be found that a small tube of radium could get at some internally diseased parts to which at present it is found impossible to send the electrical rays, but it is necessary to use great caution in applying radium rays to the human body.

There are three distinctly different kinds of rays emitted by radium, and for convenience these have been distinguished by the first three letters of the Greek alphabet—alpha, beta, gamma. The alpha (α) and beta (β) rays are exceedingly fine particles of disintegrated matter, but the gamma (γ) rays are ether vibrations very similar to, if not identical with, the well-known Röntgen rays, which we artificially produce by electrical means. The material radiations carry with them charges of electricity, and are affected by a neighbouring magnet.

In addition to these radiations it was discovered that radium gave off a radio-active gas, which is not common to all radio-active bodies. This gas has been collected,

vaporised, and even liquefied by the low temperature of liquid air.

If a long glass tube be coated with a chemical substance which will become luminous in the presence of radio-active bodies, the passage of this gas or "radium emanation" may be followed as it is sent along the tube.

It is supposed that these emanations are merely a few of the radium atoms breaking up into other forms of matter, and even then these resulting atoms are not stable, but also disintegrate, and helium gas is found to be one resultant; but as any other resulting atoms do not show signs of radio-activity, it has been found impossible to follow them. This disintegration of atoms is by far the most interesting point in connection with radium. By chemical process or, as we shall see, by electrolysis we can break up a molecule of water into two atoms of hydrogen and one atom of oxygen, but we can go no further; and for more than a century the doctrine of Dalton that the atom is indivisible, or, as Clerk-Maxwell has said, that the atoms are the foundation-stones of the universe, has remained our creed. Here, however, in radium and other similar bodies the atom itself is breaking up in the course of nature.

The radium atom, as already explained, is transformed by nature into an entirely different "element," named helium gas, and so the question arises—May we not yet hope some day to find a means of transmuting the baser metals into precious gold? At present we can neither produce or control this breaking up of the atom, and as Mr. Soddy remarked recently, we may never hope to be able to transmute silver into gold, but at some far

distant date, if this disintegration can be produced, it might be found possible to transform gold into silver, which is of lower atomic weight. Even if we could all turn our coppers into golden sovereigns our fortunes would not long be made.

It is impossible to form any adequate conception of the size of an atom, but it is of interest to gain some mental comparison. With the microscope we see tiny objects which make no impression whatever upon the unaided vision, and with a powerful microscope minute objects, measuring one fifty-thousandth part of an inch, are made visible. In this statement we have already got far beyond the range of any definite comparison, and yet the very smallest particle of matter that can be seen by the most powerful microscope contains some eighteen to twenty millions of atoms, and again, every one of this multitude comprises at least a thousand fragments, or, as Professor J. J. Thomson terms them, "corpuscles." Who can form any adequate conception of the size of a corpuscle? How many million times a million must there be in a tiny speck of water? It is very difficult even to form a clear mental picture of what one million means, and I would add my humble endorsement to the suggestion, made by Dr. A. K. Wallace in *Man's Place in the Universe*, that every town should have a public room set aside with one million dots clearly shown upon its walls, so that the young mind might form some clearer conception of the true magnitude of a million. To think of a million as the numeral one with six ciphers appended means nothing, and while we may picture a million as a thousand thousands, or as a hundred groups of ten thousand,

and so on, I do not doubt that, after becoming accustomed to a visual impression of one million dots at one time, we could form a much clearer estimate of the magnitude of such a number. The wily politician, when seeking to impress upon his constituents the money being squandered by the Government of the day, would doubtless ask them to visit the "million" room, and then imagine each dot to be a golden sovereign, and, having formed that picture, to multiply it by so many hundreds of duplicate rooms, and so on.

I have wandered somewhat from the title of this chapter, but I think it of importance that we should not be content to pass over any reference to millions without some attempt at a mental picture of their vastness. I believe it has been owing to a failure of this kind that people claimed for radium the destruction of the theory of the conservation of energy. They said, Here we have radium giving out energy, and without any loss to itself. If, however, one tries to picture this energy as being due to the disintegration of one atom per second in a million billions of atoms, while some three hundred millions of these atoms might lie together in a row inside one inch, then who can hope to live long enough to observe any perceptible loss in its gross bulk or weight?

We need not fear, therefore, that the advent of radium is going to upset all our learning, and in this connection I think the words of Sir Oliver Lodge of great interest: "A bare fact is nothing, or little, till it is clad in theory. Sometimes a fact is born before its clothes are ready. Sometimes a 'layette' has been provided before a fact is born. Radium is in the latter predicament. No fact

concerning radium need stand out in the cold for lack of shelter."

It is interesting to note how a minute quantity of radium may be detected. Without going into the detail of the apparatus, it will be sufficient to understand that if a battery be connected up to two metal plates or discs, which are separated from each other by a small air space, there will be a charge of electricity upon the opposing plates, which will seek to get across from the one plate to the other, but fail to overcome the resistance of the air-space between them. It was found that some of the rays of radium made the surrounding air a better conductor of electricity, by a process known as "ionization," and strongly exhibited by the Röntgen rays, so that if a piece of radium is brought near to the resisting air-space, the conductivity is so far improved as to allow the discharge of the electricity between the plates. All that we now need is a sensitive electrometer to indicate the amount of charge and discharge of electricity between the plates. This test is so very delicate that I have seen an electrometer indicate a discharge as soon as a small specimen of radium was brought into the room.

I fear that in this chapter I may have already given many details that are not of general interest, and so in closing I will do no more than mention that the properties of radium go to confirm the theory that the atom of matter is merely the ether in a state of violent motion, or, as some prefer to think of it, electricity itself. We then picture these electrons breaking away from the unstable atom of radium, and, by the inter-atomic motion, being

hurled into space at an enormous velocity, causing radiation, etc.

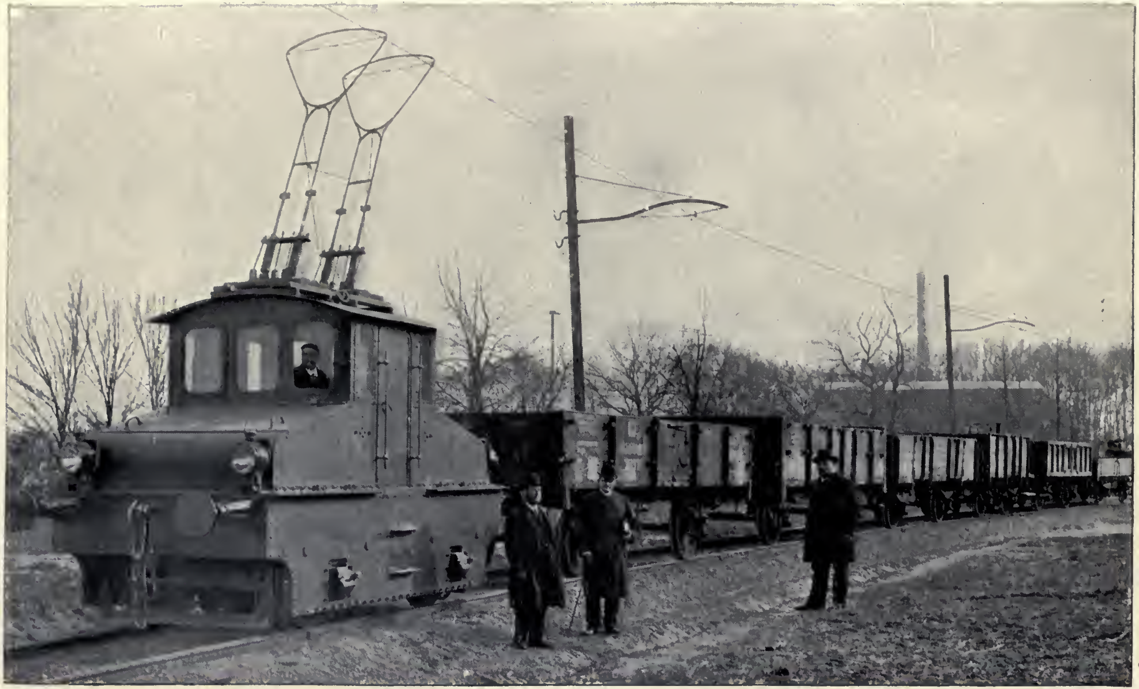
One point of very great interest to the scientific world is that radium keeps giving out heat perpetually and yet remains itself at a temperature slightly higher than its surroundings, but if we admit an energetic bombardment of disintegrated particles continually existing in the radium atom, then the production of heat due to such energy is quite in keeping with such a theory.

In order to prove that radium is continually producing electricity, a very ingenious method has been devised. A small amount of radium is placed in contact with a gold-leaf electroscope inside a vacuum globe, and the effect of the charge received from the radium is that the two gold leaves repel each other, but when they have separated a certain distance they come in contact with an earth connection, which allows the electricity to escape to earth, and then fall back to their normal position. But the leaves are soon observed to have again received a charge of electricity from the radium, and so the process goes on.

Is the old-world problem of perpetual motion solved at last? The answer must be in the negative, for the radium will in long ages disappear, and possibly long before that time the gold leaves will have refused to hold together and perform their arduous task.

Lord Blythswood has recently shown that if a piece of fine cambric, say from a handkerchief, is placed in the path of the radium rays, the fabric of the cambric shows signs of being "eaten away" in a short time.

It is now believed that all matter may in some degree



By permission of] [*The Electrical Co., Ltd.*

An Electric Locomotive fitted with two motors which receive the current from the overhead wire and return it by the rails to the dynamo at the distant generating station.

be radio-active, but if a stock of radium will not have entirely disappeared at the end of ten thousand years, and if ordinary matter be infinitely slower in its disintegration, then there may easily be a wholesale breaking up of matter, and yet it may be far beyond detection by man.

Professor Rutherford, of Montreal, has done much to fathom the mysteries of radium, and it was he who suggested the theory of the disintegration of the atom.

Doubtless before the present century is very old our knowledge of the inner workings of nature will be greatly widened through the advent of radium, and may help us to a better understanding of electricity; and our grandchildren will possibly be amused to read of some of our "old-fashioned" ideas.

CHAPTER XXV

ELECTRICITY AND CHEMISTRY

What the escape of a bubble of hydrogen gas from a drop of water led to—How electricity affects the composition of substances—Ridiculous notions get abroad—Humphry Davy finds out the true possibilities—Electricity extracts new metals from nature—What takes place when a chemical compound is treated electrically—A curious reaction—Aluminium made marketable—How goods are electro-plated, etc.

TWO Englishmen having received from Volta a letter describing his pile of metal discs, set about making up a voltaic pile as already described in chapter iii. This was, of course, before Volta had made his cell or chemical battery.

These gentlemen used silver half-crown pieces and copper discs, separating the pairs by cloth soaked in common salt. They conducted the electricity by a wire to a metal plate, and in order to make sure that they had a good connection between the end of the wire and the plate they put a drop of water on the plate where the end of the wire touched it, so that the current might also find a path through the water. While working in this manner, one of the experimenters said that he perceived the odour of hydrogen gas coming from the water, and his friend at the same time noticed small bubbles of gas in the drop of water. This seemed very strange, so to

make quite sure that they were making no mistake, they enclosed some water in a piece of glass tube and corked up both ends. They then passed the end of the one wire from the voltaic pile through one cork into the water, and the other wire through the second cork, so that the current could flow in by the one wire, through the water, and out by the other wire back to the voltaic pile. There was no mistake about the gas now; it could be seen bubbling from the end of the wire at which the current left the tube, and it was also noticed that the end of the leading-in wire became tarnished or oxidised. To prevent this tarnishing they next used a piece of platinum wire which could not oxidise, and then they found gas evolved from the ends of both wires.

In order to find out if the gases were the same, they arranged the apparatus so that they could collect the gas from each wire in a separate tube, leaving the current a free path through the water from the one wire to the other. They noticed that the tube at the leading-in wire only filled half as quickly as the other, and on examination it was found that the gases were oxygen and hydrogen respectively, there being twice as much hydrogen as oxygen. It was quite apparent that the electric current was decomposing the water, which was already known to be composed of two parts of hydrogen to one of oxygen, or as the chemist would indicate it in symbols, H_2O.

Here we have a good example of how much may depend upon the quick observation of an experimenter. These two gentlemen—Mr. Nicholson and Sir Anthony Carlisle—were not looking for any effect of the current in

the water, which was merely used to make a convenient and sure connection between the wire and the metal plate through which they wished to pass the current. The odour of hydrogen evolved from such a small quantity of water might easily have passed unnoticed, and we might not have been to-day so far forward in one of the commercial adaptations of electricity.

The effect of the current on other liquids was soon tried, and it was found that oxygen and the acids always collected at the leading-in wire, whereas hydrogen, metals, and alkalies (potash, soda, etc.), always gathered at the end of the wire at which the current left.

Sir Humphry Davy, who would only be about twelve years of age at this time (1800), was led, at a later date, to wonder whether there would be any effect if the wires were put into two separate vessels containing water, instead of both dipping into the one vessel. He tried this and found no result, but he happened to put the fingers of one hand into the water in one vessel while his other hand was in contact with the water in the second vessel, and at this moment he noticed gas evolved from both wires in their separate vessels. This seemed a most unaccountable result, so Davy got three friends to stand hand-in-hand and form a chain, and he found that whenever the two friends at the ends of the chain put their fingers into the glass vessels the gases were immediately given off in the water at the ends of the wires.

It was in following up these experiments and some others regarding the heat effect of the current that Davy first produced the electric arc between two carbon points. People began to talk and write a great deal of nonsense

about what the electric current could do. Some experimenters went the length of claiming that by passing an electric current through water they had been able to produce certain chemical compounds, no trace of which was previously in the water, as it had been carefully distilled.

Humphry Davy would doubtless be annoyed that any such ridiculous statements should get about, so he began a series of very exhaustive experiments to see what could really be done by the electric current passing through different substances. How much we really owe to these experiments it is difficult to realise. In one experiment, by passing the current through some potash (potassium oxide), which he had heated till it became liquid, Davy found oxygen gas given off, and he saw small metallic globules appear in the liquid, which metal was afterwards named potassium. From soda he produced the metal sodium, from lime came calcium, from an earth known as alumina he got the metal aluminium, and so on. To-day we have vast industries built up on these early experiments made by Davy.

Before glancing at the work done by electricity going hand-in-hand with chemistry in the industrial world, it may be of interest to form some idea of what takes place in the liquid when the current passes through it. We must picture every material thing as made up of tiny molecules, and each of these again composed of various groupings of the atoms of simpler bodies. We have already referred to the water molecule as being composed of two atoms of hydrogen to one of oxygen, and we may picture these three atoms holding on to each other, while

we may further consider this apparent attraction to be due to a vibratory movement in the atoms, or the temperature of the atoms. Whatever it may be that binds together the atoms, it is disturbed by the passage of an electric current, and we find the two hydrogen atoms breaking away from their former companion the oxygen atom, and congregating at the wire leading the current out, while the freed oxygen atoms make their rendezvous the point where the current enters.

If we take hydrochloric acid and pass an electric current through it, we find an equal quantity of hydrogen and chlorine gas at the respective wire ends or "electrodes," and this is just what one would predict, as the molecule of hydrochloric acid is composed of one atom of hydrogen and one atom of chlorine gas.

This electric analysis was named electrolysis (electro and Greek *lysis*, a loosing) by Faraday, who did so much for this and other departments of science, and to-day we have many commercial adaptations of the electrolytic process. In the great alkali manufacture, common salt (sodium chloride) is electrolysed into sodium and chlorine. When the sodium is brought into contact with water and steam it becomes caustic soda (sodium hydrate), or if carbonic acid gas is injected into the apparatus we get carbonate of soda, while the chlorine is used directly in the production of bleaching powder (chloride of lime).

The chemical effect of the electric current is also used in connection with the rectification of alcohol, the purification of sewage, the extraction of gold from the refuse or "tailings," but perhaps the most interesting is

the production of the metal aluminium briefly referred to in chapter xxvii. As stated in that chapter, the production of aluminium is not directly due to the heating effect of the electric furnace, but to chemical changes brought about by the effect of the current, which changes can only take place at a high temperature.

The production of aluminium by the electrolytic process is of particular interest, as without this means we could not have aluminium at a marketable price. Previous to the use of electric methods aluminium cost one pound sterling per pound weight, whereas the same quantity may now be bought for one shilling.

It is interesting to note that when we decompose water by the passage of an electric current, and we have the one platinum wire end or electrode with its evolved hydrogen gas and the second electrode with its accumulation of oxygen gas, there is a very strange thing that happens. If we take away the battery and connect the two wires from the tube together to form a direct circuit from the one electrode to the other, we immediately get a current of electricity flowing through this wire from the tube of oxygen to the tube of hydrogen, and through the water from the latter to the former, making a complete circuit. We first of all passed a current of electricity through the water, causing chemical disturbances, and now we find that these altered chemical conditions will set up a similar current when working back to their previous positions.

In the foregoing experiment we have the basis of the storage cell or accumulator. When referring to the action of these secondary batteries in chapter iii., in order

to explain the charging and discharging, I used as an analogy a grandfather's clock, in which we expended energy in raising the weights, and these in falling back again did useful work but soon expended the potential energy given them. We raised the weights, they travelled back in the opposite direction, and in the secondary battery or in the electro-decomposition of water the current comes out of the apparatus in the opposite direction to which we put it in, just as when we wind a spring which, in returning to normal, exerts energy in the opposite direction.

In connection with the electrolysis of water some physicists maintain that the decomposition is due to secondary action dependent on the presence of acids or salts in the water. Others suggest that the presence of these merely reduces the electrical conductivity of the liquid. In any case it is possible to decompose ordinary water without the addition of acids.

After Sir Humphry Davy had made known his electrolytic discoveries, no doubt many chemists would begin experimenting with the electric current, and it is not surprising that several independent workers claimed to have discovered that when the current was passed through a liquid containing some metal in solution, such as copper sulphate, the metal was deposited on the end of the wire from which the current left the solution. A Birmingham surgeon found that if he attached a metal object to the leading-out wire this article became coated with the metal that was held in the solution. It was evident that the electric current was causing the molecules of the solution to break up and the atoms of the

metal were gathering at the leading-out wire. The current would soon free all the metal atoms in the solution, so it was found necessary to supply further metal to the solution, and this was done by attaching a piece of the metal to the leading-in wire. If the solution used was a double cyanide of silver, and a piece of silver metal was attached to the leading-in wire, then a metal object suspended in the liquid from the leading-out wire would become covered with metallic silver, and in this way the great industry of electro-plating was founded. We have silver-plated, gold-plated, or nickel-plated goods, in which we have given some baser metal a real coat of these more valuable ones.

The object to be covered need not itself be made of metal as long as a conducting surface is given to it whereby the current may pass over the article. A mould of any object made in wax and covered with plumbago may be placed in a solution of copper sulphate, and a coat of copper electrically produced as just described. In this we have the basis of electrotyping, for if we take an engraved block and make a mould from it we can deposit a metal film over it, and then removing the mould we may back the film up with metallic alloys for the sake of cheapness, or we may make the electrotype in solid copper, so that we then have a second block corresponding to the original engraved one.

Electrotyping is practically electroplating, but the former term is used to denote that the coating produced is removed and then filled in with an alloy, whereas in electro-plating we merely add a permanent coating of a rarer metal to the object treated. This is, of course, of

great service in connection with newspapers, illustrated magazines, and books.

A plaster-of-Paris bust may be electrically covered with metal, and even natural objects, such as leaves, insects, etc., may be faithfully reproduced in every detail by electro-deposition.

As the metal deposited is always pure we have here a means of producing pure copper, the production of which, by the electrolytic process, has now become a great industry.

To get the best effect in all electrolytic operations we require a large amount of current at a low pressure, and dynamos are now specially constructed for this purpose; but batteries may, of course, be used for experimental or small work.

If the two experimenters who first noticed the escape of hydrogen gas from a drop of water through which an electric current was passing had predicted that their simple discovery would lead to the creation of enormous industries employing thousands of workers, their claims would certainly have been discredited, but to-day these great industries do exist.

CHAPTER XXVI

ELECTRICITY IN THE COAL-MINE

Edward I. prohibits the use of coal—Early ideas of getting at the coal—First attempts in using machinery underground—A trip down a coal-pit—Electric light and haulage underground—The employment of ponies underground—Electric coal-cutters at work—Men go with a powerful machine along a narrow passage only eighteen inches in height—Is the miner deprived of employment by labour-saving machinery?—The application of electricity enables old mines to be reopened and worked at a profit.

WE are all very familiar with that mineralised vegetable matter to which we give the name of coal, and no one needs to be informed that it is found embedded in the earth in large layers or seams, but a few introductory remarks may be of interest.

Although the ancients knew of the existence of coal and were aware that it would burn, they did not seek to make any practical use of it, as there was plenty of wood to be much more easily obtained.

The introduction of coal, or as it was at first called by Londoners, sea-coal, because it came to them by the sea, met with great opposition. A few years before the Battle of Bannockburn we find Parliament successfully petitioning King Edward I. to prohibit the use of coal in London as the citizens were offended at the "sulferous smoke and savor of the firing," and at a later date we

find that "the nice dames of London would not come into any house or room where sea-coals were burned."

With the increase of industries, such as iron-smelting, it became almost a necessity to make use of coal, as the country's forests were quickly disappearing. One quotation, from an interesting tract written in 1629, will serve to show how the matter then stood. An ironmaster in the neighbourhood of Durham is accused of having "brought to the ground above 30,000 oaks in his lifetime; and if he live long enough it is doubted if he will leave so much timber in the whole country as will repair one of our churches if it should fall." It was not, however, until the eighteenth century that coal came to be used in iron-smelting.

The invention of the steam-engine gave a great natural impulse to the use of coal, for it not only became a large consumer, but it also made the "winning" of coal from the bowels of the earth a much easier task.

The first idea of obtaining coal was to open up the ground as is done in a stone quarry: then followed a system of tunnelling into the bottom of a hill in which seams of coal were known to exist. Obtained in this way the early coals would be of inferior quality, being taken from near the surface, so that the "stench" complained of may have been greater than the smoke to which we are now accustomed.

It was soon found that the best seams of coal were buried too deep in the earth to be got at by the opening up of the ground, and there was nothing for it but to dig a deep hole or pit down which men might be lowered into the earth. Mines have been sunk as deep as 3,490 feet,

By permission of *Siemens Schukert Werke.*

1. A HIGH-SPEED ELECTRIC TRAIN

The electric motor may be placed below the passenger car and directly coupled to the axles. Electric cars built upon this plan have attained a speed of 130 miles per hour.

2. AN ELECTRIC TRAIN IN A COAL MINE

By means of electricity power can be conveyed into mines to electric locomotives, which are thus driven by the dynamos situated above ground.

or considerably over half a mile down below the surface. The seams vary from a few inches to more than thirty feet in thickness. Coming to a seam of coal, it is the duty of the miner to cut away the "black diamond" and send it to the surface, and it is in connection with the cutting of the coal that electricity is already playing a most important part.

Till quite recently it has been necessary to do all the hard work by manual labour, because of the difficulty of carrying energy to any mechanical appliances deep down in a mine. Attempts were at first made with long connecting rods or shafts from an engine on the surface, reaching down to the bottom of the pit. In some cases even engines and boilers were placed away down in the earth, more recently compressed air was used, and is still in use; but what a stride we have now made in being able to carry electrical energy from the surface along a stationary wire, away down into the mine, and into the most awkward coal seams, there to drive a motor attached to a machine.

As it is not convenient for everyone to visit a coal-mine, it may be of interest to give a brief description of the different ways in which we find electricity serving the miner.

Having gone by train into the country, the visitor makes his way to the pit-head, where he finds an engine-house in which an engine is driving a dynamo and generating current. He first of all notices a cable stretching from the engine-house away across the fields, and he learns that this cable is conducting current to an electric motor, placed on a river bank, about a mile distant, and

that the motor is there driving a pump which, in turn, is forcing water from the river through a pipe to the engine-house. Instead of having a small engine and boiler at the river with someone in attendance, this little motor, quite unattended, is under entire control from the distant engine-house.

In a separate building the visitor finds another engine, or it may be an electro-motor, for raising and lowering the cages in the pit-shaft, and if he is of nervous temperament he may drop a hint to the engine-driver that he has no desire to feel the sensation of flying down the pit-shaft at full speed. Getting on to the cage, the novice is warned by the manager to take a good grip of the iron bar overhead, and as soon as he is plunged into darkness he is rather alarmed, if it be his first experience, to hear a sudden deafening clatter immediately overhead, which he is informed is caused by the "policeman," this name being given to a very heavy trap-door which falls over the pit mouth as soon as the cage enters the shaft. It seems a long journey to the pit bottom, but the engine-driver is putting the stranger down more cautiously than he does the experienced miner. If the pit be one of 2,000 feet in depth, the visitor welcomes the bump which assures him he is at the end of his downward journey.

If the explorer has expected to find himself in a large spacious underground coal quarry, he is disappointed. Even if the mine be an important one, there is no more open space in the pit bottom than one finds in a large room, and from this space a number of tunnels or roads lead off in different directions. The coal here has not been touched, except to make these passages through it,

for it is necessary to leave the earth as solid as possible all around the pit-shaft. No matter how valuable the coal seams may be, the miners must travel two or three hundred feet along these main roads before they touch any coal.*

Before setting off to explore the mine the visitor is attracted by the noise of machinery, and in this particular mine he has no difficulty in finding his way about, as the bottom and the main roads are equipped with incandescent electric lamps, connected to the dynamo aboveground. He finds the noise to come from a room close to the pit bottom, where an electro-motor, also connected with the dynamo aboveground, is driving a number of large drums, each of which is hauling in or paying off a long wire rope. Each of these haulage ropes passes right along one of the main roads, lying between the rails of a narrow-gauge track, so that the little trucks, called "hutches" or "tubs," may be hauled to the pit bottom and then sent up the shaft to be unloaded.

The motor-man has a series of electric bells of different sounds, each one representing a different road, and as two bare wires are led along the roof of each main road, the miner can make the wires touch each other at any place, and thus signal to the motor-man to haul in his train-load of coals. Touching the wires together is equivalent to pressing a bell-push.

In this case the electro-motor is stationary, and merely hauls in the wire rope, thus propelling the hutches, but in

* The descriptions refer to the working of a mine on what is called the longwall system, consecutive slices being taken off the whole face of the seam.

some mines, such as American drift mines, where an inclined tunnel is run into the mine instead of a perpendicular shaft, the motor may be carried on a small truck, thus forming a miniature locomotive, and receiving power from a fixed conductor overhead, just as an electric tramway car does.

Ponies are still used underground for hauling the hutches along the side or branch roads to the main roads, and at present it looks as though these could not very conveniently be replaced even by electricity; but it is quite a mistaken idea to suppose that these ponies are blind or that they are in any way ill-used. My experience on visiting mines, where sometimes as many as thirty ponies are at work in one pit, has been to find the animals in excellent health, well cared for, and most kindly treated, and I have seen nothing to indicate that any of these ponies had a grievance.

The inexperienced sightseer may make his way along one of the main roads expecting to come upon a large space with a crowd of miners all together clearing it of coal, but such expectations will not be fulfilled, for he will find nothing but a series of roads or tunnels.

When the visitor gets away from the main road he finds he can no longer stand upright, but has to walk along with his body bent at right angles, and even then his guide will warn him occasionally to watch his head, or to be careful not to touch the roof at some particular place as it is "just hanging." As he walks along, guided by the light of a small lamp, the visitor notices some cables hung up in a very temporary fashion on the walls of the road or from the roof, and he learns that these are

conveying electricity to the coal-cutting machines. He need not ask why the cables are so loosely tied up, for he soon comes upon a "fall," where the roof has come down and almost blocked the whole road, leaving the visitor to climb through a space that is only entitled to be called a hole. Here the cables have come down with the roof, but being slack and only insecurely fastened they have offered no resistance to the fall, so that no damage has been done. The fall will soon be cleared away, and wooden props put in to secure the roof. In some mines where there are bad roofs one finds in these roads whole regiments of wooden props, which continually require renewal, as they give way under the great pressure.

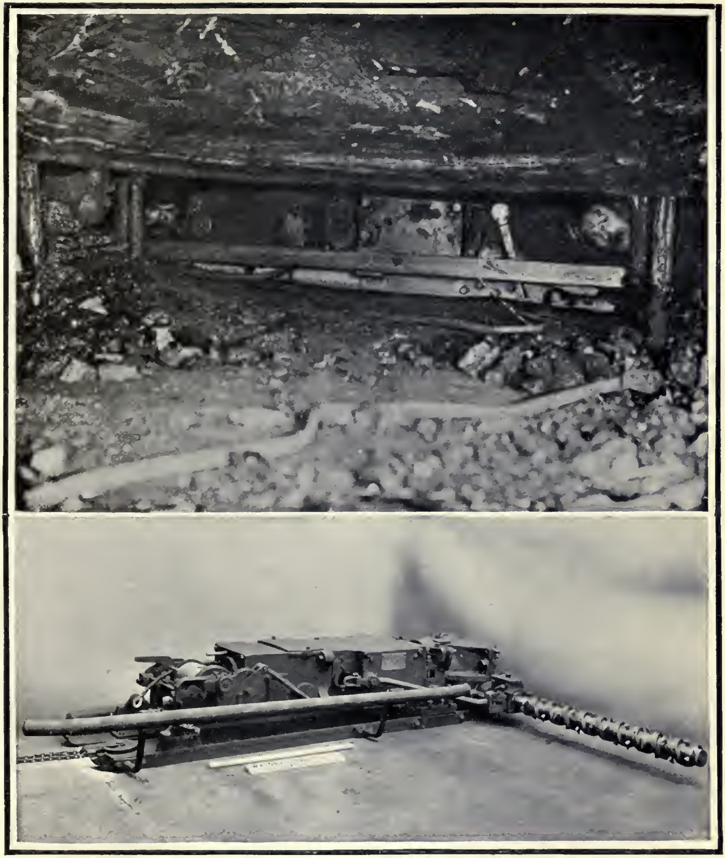
From this side road, which the visitor has been walking along, there are a dozen narrow passages branching off at right angles to it, but there is no sign of coal-cutting yet. These twelve roads, about sixteen yards apart, lead up to the coal seam. This seam, which could originally be seen along the wall of the side road, has had a number of slices cut off its whole length, and as each slice was taken out the cavity was filled in with stone rubbish taken from these passages, their roofs being cut away to give the miners room to draw in the hutches or trucks and get the coal away.

The visitor enters one of these twelve passages, being informed that he is in road No. 8, and as this seam has been worked for some time, he finds he has quite a long way to travel in a very cramped position, for it is difficult to avoid touching the roof with his back. On reaching the end of this road he comes to what at first appears to be a dead end, and as he has come during the night-time in

order to see the electrical coal-cutters at work he finds no one in this road at all. He soon hears the hum of machinery in the distance, and on taking his lamp to the apparent dead end he finds a narrow passage only eighteen inches in height and four feet wide running right past the end of his road.

If the visitor cares to crawl or "worm" his way along this narrow passage, he will soon come on the end of No. 7 road, and then a little further on the end of No. 6 road, and so on, all these roads leading up to the face of this same seam, but as the noise of machinery is drawing nearer, and as everywhere it is pitch dark, he prefers to crawl back to the entrance of his road. Very soon he hears two men calling to each other occasionally over the hum of the machinery, and in a little he discerns a miner coming creeping along this narrow passage with a pick and shovel, clearing the way for the electric coal-cutter. It is no easy task to use a pick and shovel while lying flat down with only eighteen inches between the floor and the roof, just about the space below an ordinary chair seat. Close behind this man comes the coal-cutting machine, sliding along on skids, and as the machine practically fills the whole space, the visitor cannot get a view of it till it comes opposite the end of his road. (It is in this position that the accompanying photograph was taken.)

When the machine comes within sight and passes the end of his road, the visitor finds it is drawing itself along by means of a haulage rope, which is fixed at some distance along the passage, and is being gradually wound on to a drum in the machine. The machine,



AN ELECTRIC COAL-CUTTER

Two miners working an electric coal-cutter in a mine, reproduced from a photograph taken in a coal mine. The men's faces are seen peering out at the two ends of the machine. These men have to creep along a narrow passage which only measures eighteen inches from floor to roof, and they work hard in this confined space right through the night. In the lower illustration, by permission of Mavor and Coulson, Glasgow, the coal-cutter itself is shown.

which is about eight feet long, is followed by another miner, who is controlling the working of it. From one side of the machine extends a long arm or drill fitted with small points or "picks," and this arm or bar has both a rotary motion and a to-and-fro or saw-like motion at the same time. The bar or cutter is put into any desired position, and may be arranged to cut away the fireclay below the coal seam, or if, instead of fireclay, there is very hard rock or "pavement" beneath the coal, the cutter bar can be adjusted to cut along the top of the seam. This particular seam, which the visitor is watching, is being undercut, and what the machine really does is to cut away the foundation from the coal, the bar going in three and a half feet or even further.

The coal-cutter travels along the existing face of the coal seam, cutting away the foundation and leaving a space of less than five inches in height for three and a half feet in under the seam, and in one night this machine, requiring only the attention of two men, will cut from one hundred to one hundred and fifty yards in length. Of course the rate of progress is very dependent upon the space in which the miners have to manipulate the machine, for as new picks have to be put in several times during the night, this operation will take much longer if the miner has to do it while lying on his face, side, or back. In a deeper seam the miner can use his tools more easily, and the largest cut of which I have any direct evidence is one in a three-feet seam, where a length of two hundred yards was undercut to a width of five and a half feet in ten hours' time, for six hours only of which the machine was actually working, which means a speed of

more than a foot and a half per minute. The nature of the soil underlying the coal also determines the speed of the machine and consequently the distance cut per night.

When the coal-cutting machine has cut away the foundation from the coal it has done the hardest part of the work. One can imagine a miner having to cut away the foundation of an eighteen-inch seam by hand while lying down; he would probably do five yards by the time the machine had done one hundred and fifty yards, but it would never pay him nor his master, so that narrow seams were formerly left in the earth. They are now being worked out by these electric coal-cutters.

The seam having been undercut by the machine it only remains to bring the coal down. It may be that gravity has already brought it down during the night, but if not the "fireman" will in the morning drill a few holes in the seam and blast it down, so that it only remains for the collier to clear away the coals, fill his hutches, and leave the seam clear at the end of the day for the machine to work in during the night. As already explained, the cavity between the roads is filled up each day with stone rubbish—that is to say, the whole space formerly occupied by the slice of coal that has been removed is now filled in with rubbish, leaving only the continuation of these branch roads through it. When the slice is cut away the stone rubbish is not, of course, built in close up to the seam, for sufficient room must be left to let the electric coal-cutter work right along the face. If the visitor now creeps along the face of the coal seam he finds himself in a passage about four feet wide, but only eighteen inches

from floor to roof, and as he goes along he passes the ends of these branch roads, any of which will lead him down to the main road.

While I say that the electric coal-cutter has done the hard work, I do not mean to belittle the remaining work of the collier, for it is no light task to work in a narrow underground tunnel all day. Again, one has to remember that whereas the collier formerly sent up about two tons of coal per day, he has now to send up four or five tons of the coal cut by these electrical machines. He cannot expect to be paid the same price per ton as formerly, as his master has expended money in cutting the coal for him by the electrical machines, but his wage remains as good as before.

Some people will picture the paying off of a large number of miners whenever these labour-saving appliances are introduced into a mine, but on putting this question to the manager of the Holytown Collieries (Scotland) I learned that this was not the case. The output of the pits is greatly increased, and a fourth pit has been opened at this particular colliery, affording full employment for all their hands.

Some idea is given of the work underground by the accompanying photograph. It is curious to watch two men entering what is little more than a "crack" in the earth, and taking with them a powerful machine, which is receiving power from the surface by means of an electric cable.

The taking of this photograph was by no means an easy task, not only because of the very confined space in which to produce sufficient light, but also owing to the

intensely black surroundings. I am indebted to Mr. Diessner, of Glasgow, for his kind assistance in securing what at first seemed an impossible picture, and also to Mr. Stewart, of Pollokshaws, for aiding me in making preliminary experiments.

In view of the report of the Royal Commission on Coal (1905), it is interesting to note that old mines are now being reopened, and narrow seams that formerly could not be worked are now being cut, at a profit, by electrical machinery.

CHAPTER XXVII

ELECTRICITY AS A HEATING AGENT

What Sir Humphry Davy discovered—Arrival of the electric furnace—The greatest temperature produced on the earth—The industrial electric furnace—Electric welding, etc.—Electric heating in the home—A new industry.

WHEN Sir Humphry Davy produced an electric arch or "arc" between two carbon points, he was greatly impressed with the immense heat produced, and he wrote, "platinum is melted as readily as wax in the flame of a candle." The temperature of the arc itself, that is, say, of the bridge of carbon vapour between the carbon points, is somewhere about 3,000° Centigrade, or 5,432° on Fahrenheit's scale.

The idea of constructing an electric furnace was a natural result of Davy's discovery. An electric furnace is simply an electric arc with suitable means for enclosing the heat and preventing its escape. It has been found possible, by using special means for conserving the heat, such as lining the furnace with blocks of pure carbon and encasing it in some very refractory substance, to bring the temperature up to 4,000° Centigrade, which is 7,232° Fahrenheit. In the industrial electric furnace it is quite

easy to obtain temperatures from 2,000 to 3,500° Centigrade, or 3,632° to 6,332° Fahrenheit.

To assist in realising what an intense heat this means, it may be stated that cast-iron melts at 1,100° Centigrade, or 2,012° Fahrenheit, and from particulars already given it will be seen that it is possible in the electric furnace to reach a temperature nearly four times as great.

Some electric furnaces may be arranged to deflect the heat to any particular point, as is done in an ordinary blow-pipe. This result is obtained by using an electro-magnet to act upon the arc, which behaves exactly as a conductor carrying an electric current, and thus having a magnetic field it can be repelled by a magnet of similar polarity.

There are many devices for regulating the arc, but the general principle of the furnace is understood from the ordinary electric arc-lamp, and the simpler an electric furnace is the better in practice, as all its parts are subjected to an intense heat.

There is another class of electric furnace on the same principle as that employed in the ordinary electric glow-lamp, in which lamp a carbon filament is heated by the current. In this furnace a current is passed through a resisting core, which, being usually composed of carbon, either granular or in rods, offers a very great resistance to the current and is raised to an intense heat. Such furnaces are termed "resistance furnaces," and in some of these the material to be heated or melted is used as part of the conducting core.

The expense of obtaining a great heat from electricity is very considerable, for only a very small proportion of the energy used in generating the current appears as heat. It is obvious that under present conditions the electric furnace will not replace the much more economical blast furnace, etc., but under circumstances where a fuel is not easily obtainable and where water power is abundant the electric furnace is a very convenient means of converting the energy of the waterfall into heat. The chief use of the electric furnace is to obtain very high temperatures beyond any other known means in practice.

There is a third kind of electric furnace which will be better understood from the chapter on "Electricity and Chemistry," as it is the chemical action of the current upon the materials that is made use of, while the substance is kept in a heated condition. These are known as electrolytic furnaces, and it is this class of furnace that has made aluminium a marketable metal.

Where an intense heat is required at any particular point, such as in welding boiler plates, etc., the electric arc is very convenient, as it may be taken to any part of the boiler, one of the wires from the dynamo being fastened to the boiler plate, while the other is fixed to a portable insulating holder. As soon as the carbon is made to touch the plate and is then withdrawn about a quarter of an inch, an arc is formed and an intense heat produced.

There are many different uses to which electric heating may be put, and among the latest is a small furnace

by which dentists may fuse a very refractory substance as a filling in teeth. The dentist may also use electricity for heating air to be blown upon a tooth for drying purposes, thus obtaining a stream of air at constant temperature.

It is quite possible to cook food by means of electricity, but it is at present an expensive luxury. It is very convenient to be able to switch on the current to a kettle on the breakfast-table and reboil the water for those foolish young friends who think life is so long that they can afford to spend nearly the half of their time upon earth in their beds.

It is very nice, especially in summer time, to let the laundry-maid do her ironing without requiring a roasting fire by simply heating some highly resisting wires in the heating-iron by passing a current of electricity through them. The cook finds it an advantage to switch on the heat to her range without bothering about the laying of a fire. The whole house may be very comfortably warmed by electricity, and even bed-quilts heated by fine wires inside have been made, whether with or without the knowledge of the Fire Insurance Companies I cannot say, but these are certainly luxuries for those who, fortunately or otherwise, do not require to keep an eye on the amount of their household expenditure.

In connection with the electric furnace, it may be mentioned that within the last few years there has sprung up a new industry in the manufacture of "peat-coal." The peat is carbonised in an electric-resistance furnace, and may be produced at about five shillings per ton.

A NEW INDUSTRY

Among other uses of the electric furnace the most prominent are the manufacture of glass and phosphorus, and the production of carbide of calcium which is required for the making of acetylene gas.

CHAPTER XXVIII

ELECTRICITY'S RELATION TO HEAT

Our fickle sense of heat—Early ideas about heat—Different origins of heat—Heat produces electricity and electricity produces heat—A thermometer so sensitive that it will measure to the one-millionth part of a degree—How it is possible to measure temperatures up to thousands of degrees—A tell-tale instrument that reports any carelessness in furnace stoking, etc.—A simple experiment shows a very close connection between heat and electricity—What our great-grandchildren will think of our "up-to-date" methods—The increasing need of specialists—Some remarks about ether waves.

OUR sensations of heat are merely comparative. It is amusing sometimes, on going out of doors in the morning, to note the different opinions as to the prevailing temperature. One is sometimes greeted with the remark that it is a cold morning, while within a short distance someone else remarks that it is a mild morning. People compare the temperature with the condition of their own bodies, and if one person steps out of the cold air into a warm room he may say the latter is much overheated, while the occupant finds it just comfortable. This is very forcibly demonstrated by the simple experiment of taking three basins of water, having the centre one filled with tepid water, and one of the others with very hot water, while the third has very

cold water. Keeping the one hand in the hot water and the other hand in the cold water till they become accustomed to the respective temperatures, and then plunging both hands into the tepid water, the hand from the hot water complains of the coldness of the tepid water, while the hand from the cold basin feels the same water warm.

A youngster would consider his bath quite warm enough, and possibly too warm, at 100° Fahrenheit, while a complaint would be made that his porridge or tea at the same temperature was too cold. It is clear, therefore, that we cannot depend upon our own sensations; we must pay attention to the effects and origin of heat in other things.

Electricity has proved a most useful assistant in the investigation of high temperatures, as will be shown at the close of this chapter, but this is not the main relationship indicated in the title used for the present chapter.

The early scientists believed heat to be some subtle material substance which could be expelled from one body and taken up by another, but we now know that heat, as reaching us from the sun, is merely an ether disturbance, which, falling upon the material things of this globe, including our atmosphere, sets the molecules into rapid vibratory motion, and that this vibratory movement may be increased to a point at which the molecules can no longer hold together, so that a solid, by the application of heat, becomes a liquid, and in turn a liquid becomes gaseous. We also use the word heat to signify this molecular vibration in a body. Travelling in an opposite direction, we find that a compound gas, such as air, or a simple gas, such as hydrogen or oxygen,

will, when the vibratory motion called heat is reduced, become liquid, and when a sufficiently low temperature is produced liquid air may even become frozen or solid; and if it were possible to reach a point of absolute zero, at which there would be no vibratory motion, the molecules would doubtless fall to pieces. Following this line of thought, one is tempted to wonder whether if it were possible to rob the atoms of all internal motion they would not cease to be matter and become part of the great ether ocean.

We have a mechanical origin of heat, as is forcibly exhibited when a steam-hammer, by repeated blows, raises a piece of iron to a red heat. There is also a chemical origin of heat, as daily demonstrated in our fireplaces by the chemical changes we call combustion. But what concerns us most in this chapter is that there is an electrical origin of heat, as is exhibited in an electric lamp, or, indeed, in any conductor carrying an electric current. In addition to these there is a radiative origin, as already indicated by reference to the sun sending out ether waves which produce molecular movement in matter.

We have seen in a former chapter that while electricity may produce magnetism, the converse is also true, for magnetism produces electricity. In the dynamo we found mechanical motion producing electricity, while in the motor we saw electricity transformed to mechanical motion. In a similar way, while electricity produces heat, it is likewise true that heat produces electricity.

In the twenties of last century Professor Seebeck, of Berlin, was experimenting with simple couples of metals,

and thereby studying the Volta contact theory referred to in chapter iii., when he observed that if the point of contact of any two metals was heated a constant current of electricity was set up in the connecting wire. This was easily demonstrated by placing a pivoted magnetic needle, to act as a detector of current, upon a block of the metal bismuth and forming an arch of copper over the needle, the copper being joined to the bismuth at the two ends of the block. When a lamp was placed at one of the junctions of the metals, the magnetic needle turned outwards, indicating a current of electricity flowing in the neighbouring metals, just as the needle telegraph replies to the current in its surrounding coil. In this way it was found that if any two dissimilar metals were joined together and the junction heated, there would be a flow of electricity in a wire joining the two extremities of the metals together, provided these were kept at a lower temperature than the junction.

Electricity produced by such means is termed thermo-electricity, the name merely indicating its source. People set about making batteries or "piles" of these couples, but the electro-motive force of such a thermo-couple was found to be very small when compared with that of an ordinary voltaic cell. Bismuth and antimony are the metals usually employed for experimental thermo-couples, but these are of chief interest to the scientist.

One practical adaptation of the thermo-couple is in obtaining very exact measurements of differences of temperature, one invention being capable of detecting a difference of less than one-millionth part of a degree. Of course, an instrument of such delicacy is not required in

everyday life, but it is useful in a scientific laboratory. It is very important, however, in the industrial world that we should have means of reading very high temperatures, such as the heat of a blast furnace or a pottery kiln, and for such purposes a thermo-couple comes in as a very useful servant.

If a thermo-couple, protected in a fireproof porcelain tube, be inserted in the source of heat, the temperature of which is desired to be known, there will be a current of electricity passing out along the connecting wires, and this current will be in proportion to the amount of heat producing it, so all we now require is a delicate galvanometer, which is a magnet capable of turning in a surrounding coil of wire, to indicate the presence and the amount of the current. The more current that passes, the farther will the magnet be turned round, so that a scale may be marked off representing heat degrees, and so arranged that the magnet will point out the temperature corresponding to the current set up by that particular degree of heat. Such instruments are generally called pyrometers, and are capable of reading temperatures as high as 3,000° Fahrenheit. They may be made to read any temperature, provided the thermo-couple is able to withstand the heat.

Pyrometers may be made to record the variations of these high temperatures, and one can imagine these little tell-tale recorders locked up all night in the darkness of the manager's private office, but truthfully informing him in the morning of any carelessness or irregularity on the part of those whose duty it is to keep the furnaces, etc., at a constant temperature.

By permission of *The Scientific American, N.Y.*

AMERICAN ELECTRIC ORE-LOADER

This electrically driven ore-loader is shown backed up to a great heap of ore in one of the large steel works in America. It is provided with clutches, and it automatically loads the iron wheelbarrows, in which the ore is carried to the blast furnaces.

The electro-magnetic effect of the coil upon the magnet is so very small that much skill is required in the making of these instruments, and I have seen a difficulty arise from such a small cause as a trace of iron being in the brass of a very small screw, which being carried by the indicator affected its behaviour towards the thermo-current. A well-made pyrometer is quite reliable, and this is a use of thermo-electricity which, no doubt, will be valued more as our industries advance along more scientific lines.

Although thermo-batteries have been used in France for working telegraphs and even for lighting glow-lamps on a small scale, their present use is as a sensitive measurer of very slight differences of temperature, and as an indicator of extreme heat or cold.

It would be folly to think that scientists have already got to the "end of things" as regards the most economical method of obtaining electric currents. Ultimately man may find a means of dispensing with the clumsy method of converting heat into mechanical energy by means of the steam-engine, which is done at an enormous loss, for it is a remarkable fact that the very best steam-engines of our times can only give us about twelve per cent. of the energy in coal. Our great-grandchildren will doubtless consider our "up-to-date" methods very crude, for with the steady advance of scientific knowledge, there is bound to be an equivalent advance in the industrial world.

The short time we are upon this earth does not give us opportunity to explore thoroughly more than a few of the main paths of knowledge, or possibly only a single main

road and some of its side lanes or ramifications, so that as the accumulation of knowledge goes on at a quickly increasing rate, the need of specialists will become even much more marked than is the case at present.

In closing this chapter, it may be remarked that although heat waves in the ether were, until quite recently, believed to be entirely different in character from light waves and actinic or chemical waves, the distinction is fast disappearing, and the tendency is to consider all these ether waves as "light" waves whether affecting the vision or not, and it is in this connection that a new word is required to save confusion with the word "light" as used to denote a sensation. It is now becoming more common to speak of heat as the phenomenon exhibited in matter, and to call the heat waves in the ether "radiant energy."

All ether waves are set up by the vibratory movement of molecules and atoms of matter. As already indicated, the molecular energy in the sun disturbs the all-pervading ether, which again sets up molecular motion in matter, and so on.

The connecting link between matter and the ether will be explained when we come to consider what we know about electricity.

CHAPTER XXIX

HOW ELECTRICITY AIDS THE CONJURER

A spirit séance—A most remarkable borrowed penny—How the audience are led astray—A wizard of sixty years ago—An extraordinary mansion.

ELECTRICITY is a very helpful assistant in enabling the conjurer to delude his audience. There is no mystery now in a drum beating while suspended in the air, or in musical instruments playing in inaccessible parts of a hall, as the public have become well versed in the electrical transmission of power; but a very good representation of a "spirit-rapping séance" may be given by similar means. It is not my intention to attempt to expose the methods of any public entertainer, but on several occasions I have concocted and performed some electrical "magic" for amusement at entertainments given in behalf of charities, and I shall use some of these as illustrations of how electricity aids the conjurer.

In order to give an imitation of a spirit séance one may place an empty tin box upon a little table at the front of the stage, and then, calling on the ethereal spirit to come and make itself manifest, make the audience hear, above the soft musical refrain from the piano, a distinct series of raps, first of all in some inaccessible corner, and

then coming gradually nearer the stage till the rapping is distinctly heard upon the table, and ultimately upon the empty tin box, which has been previously examined by one or more members of the audience and placed by one of them upon the table.

If one of the audience now selects any card from a pack of playing-cards, the spirit will tell the number of the card, and when asked to answer by a single rap whether the card belongs to hearts, clubs, diamonds, or spades, it will remain silent till the right suit is named, and the conjurer is able to assure the audience that he did not know what card had been selected until he heard the raps from the empty box. A good deal of amusement can be obtained from such imitations, and there can be little secret here to disclose, for it is evident that the raps are produced by hidden electro-magnetic devices similar in principle to an ordinary single-stroke bell. The raps on the empty tin box are really taking place on a long flat tin box concealed under the table-top; and all these devices, placed in different parts of the room, are under the control of an assistant behind the scenes.

The rest is mere trickery, as, for instance, with the cards. The conjurer has one complete pack of playing-cards, and in addition many packs of the same appearance, but each of these consisting of fifty-two cards of one particular value, the ace of spades, the ten of diamonds, and so on. The conjurer, of course, merely exhibits the complete and honest pack, and while he is asking a member of the audience to select any card, he exchanges the pack for one of the faked ones. In order that he may say to the audience that he does not know the selected

card, he simply picks up at random any one of the faked packs before going on the stage, and, without looking at it himself, he hands the hidden confederate one of the cards, so that this assistant controlling the electric switches will now be able to cause the tin box to rap out the number and suit of the card which will necessarily be selected by the audience. This séance may, of course, be extended in a great variety of ways.

To take as another illustration a trick which I recently invented, and which met with the approval of a large audience. Coming upon the stage I place two small tables in the front, one at either end of the platform. I then request the temporary loan of one penny, which is easily obtained, but so that there may be no misunderstanding I ask the lender if he will be good enough to mark the penny with his knife in any way he desires so that he will not fail to recognise it again. This having been done behind my back, I request a lady, close at hand, to seal the penny up in an envelope and retain it meantime. Going upon the stage I exhibit an empty tin box, and assuring the audience that it is empty and contains no hidden machinery of any kind, I request that anyone desiring to examine the box for himself should do so. A gentleman comes forward, but as soon as the box is touched it deals out a series of sudden shocks, so that the examiner refuses to have anything more to do with it, and no one else seems willing to risk electrocution, while the convulsive jumps of the would-be inspector have given the audience and himself some amusement. Remarking to the audience that I suffer no inconvenience in the handling of the box, I proceed to close it, not only

putting its lid on, but also tying a ribbon around it to ensure the lid remaining firmly closed. Holding the box by the ribbon I place it upon four glass tumblers, which act as transparent legs to keep the box clear of the table, and insulated from the rest of the material world. Now taking a pasteboard box down to the audience I request the lady, who has meantime held the borrowed penny, to place it and its enclosing envelope inside this box, she tying a ribbon around it to prevent my opening it. Carrying this box by the ribbon, and keeping it in view of the audience all the time, I place it upon four other glass tumblers on the little table at the opposite end of the stage from the tin box. Then standing right in the centre of the stage, I tell the audience that the borrowed penny is now in the pasteboard box, securely sealed up in the envelope, just exactly as the lady placed it there. It may be remarked here that some people think that a conjurer has a special licence to say a thing is somewhere when it is not, but that is never the case. He may pretend to place something where he really does not, but when he tells the audience that the borrowed article is in a certain place, then it really is there. Thus assuring the audience that the borrowed penny is still in the pasteboard box, I ask them to pay particular attention to my movements, watching that I never go near either of the tables. I then command that the penny should break up into its individual molecules, so that it may easily pass out through its imprisonment. A little gentle music from the pianist and I inform the audience that if they can see a sort of mist hanging over the stage they can then see the penny in solution.

I then command that the penny shall, after a few bars of lively music, quickly rush together again and fall down inside one of the four tumblers under the tin box on the other table. At the moment when the music ceases the penny is distinctly heard to fall into one of the tumblers, but not satisfied with this, and still standing in the centre of the stage, I ask the penny to once more quickly disintegrate and pass through into the tin box. A few bars of music and the audience, listening to the movement of the penny, are satisfied that it has entered the box, but to show how well under control it is, I ask the penny to spin round on the bottom of the box. This done, and still remaining in the centre of the stage, I request the gentleman who was good enough to lend me the penny to come up on the stage himself and open the tin box, and I ask him to tell the audience quite frankly whether or not it is his penny that is now in the tin box, and I assure the gentleman that if he finds the marks as he made them he may be certain that there is no trickery there, as I have not the faintest idea how he marked the coin, nor has any confederate seen or handled it.

Having removed the ribbon and the lid, the lender carefully examines the penny, which he emphatically declares to be the borrowed penny and no other.

I then ask the gentleman if he will be good enough to lift the pasteboard box off the other table and take it down to the lady who deposited the penny in it. She finds the envelope empty, but without any trace to indicate how the penny escaped.

More than one scientific friend remarked to me after the performance, that if it was really true that the

borrowed penny was still in the pasteboard box after I left it on the table, it seemed an utter impossibility that the lender should find it in the tin box. I not only assured them that the penny was left in the pasteboard box, but it was also true that I never handled the borrowed coin after handing it over to the lady for sealing up in the envelope.

All this, doubtless, seems mysterious, and yet it is very simple from behind the scenes, for it is very much easier to make up an entanglement of this kind than it is for an outsider to disentangle it.

First of all the electrical apparatus is very simple and is merely to deceive the sense of hearing, upon which the audience are going to depend as to the whereabouts of the borrowed penny. I first of all made up a flat glass vessel, to be placed immediately under the table-top, and I supported a penny over this glass box by drilling a hole in the coin and passing a fine silver wire through it and over the top of the box. The silver wire was connected to wires leading down the legs of the table and thence under the carpet to the back of the stage, where an assistant could switch on an electric current and fuse the fine silver wire, allowing the penny to fall into the glass vessel at the desired moment. This jingling noise of the falling penny really takes place, of course, in the glass vessel immediately under the table-top, but the audience believe it to occur in the tumbler. A similar stretched wire and penny placed over a hidden tin box completes the deception as far as the dropping of the penny is concerned. Another tin box with a simple electro-magnetic device sets a penny spinning on the bottom of a box. The

audience hear these sounds while intently watching the box and tumblers on the top of the table, and the deception is wonderfully efficient.

While the conjurer here depends upon electricity to produce the desired effect as far as the senses are concerned, there must be an attempt to mystify the mind, or to lead the thoughts of the audience astray. The most misleading part of the trick really consists in my being able to deceive the audience as to the identity of the borrowed penny.

To make the matter quite clear let us first of all merely follow the borrowed penny. I took it from the gentleman, handed it to the lady, who sealed it in an envelope, and later on placed it in the pasteboard box. The box was taken on to the stage, the penny was never touched, and still lay there where it was put till the trick was over and done and the audience away. I made the box with a false bottom so arranged that it at first acted as one of the sides, being folded back against the real side, and I had previously placed an empty envelope, identical in appearance to the one I gave to the lady, between the false bottom and the side, so that when the lady deposited the envelope with the borrowed penny in the box, the false bottom closed down upon it, safely hiding it and exposing in its place the empty envelope, to be discovered there later on. This was the borrowed penny, but it was not the penny the lender marked, for when he handed me the penny at the outset I pretended just to recollect, as I was taking it from him, that it would be better to mark it, whereas I really handed him another penny of my own which I had hidden in the

palm of my hand. He took this penny believing it to be the penny he had just taken out of his pocket, and if questioned I doubt if he would admit that the penny ever left his hand, and so he marked this penny of mine. I retained this marked penny, leaving the borrowed penny with the lady, and while the audience were laughing at the eccentricities of the gentleman who got a shock on touching the tin box, I placed this marked penny on the bottom of the tin-box, then put the lid on and tied it up.

The trick was, of course, really over, as far as I was concerned, before it had begun in the minds of the audience, and this is a safe principle upon which to build up a trick.

I was able to say truthfully that the borrowed penny was in the pasteboard box, and it was the lender who examined the marked penny in the tin box and said that it was his penny. It certainly was the penny he marked, but not the borrowed penny, and so the mystery was obtained.

In order to deal out electric shocks from the tin box to the would-be inspector I had previously deposited two large pieces of sheet-iron below the carpet, and connected these to a battery and induction coil, under the control of an assistant behind the scenes. When I stood on one hidden plate, and the member of the audience over the other plate, we completed the circuit through the box in our hands. Of course I received a similar shock to the victim, but, being prepared for it, I took it more calmly. This part of the trick was merely a "blind" to give the amateur conjurer a safe opportunity of placing the marked penny in the box without attracting attention.

One would hardly credit how much the audience really see in their imagination. I have heard the narration of some of my own tricks by members of the audience, and it is really quite remarkable how the actual facts are altered by their imaginative powers. This somewhat lengthy description will serve to illustrate the application of electricity to the "black art."

A very interesting account was published, about a quarter of a century ago, of how Robert Houdin, a famous French conjurer, amused himself after his retirement to a beautiful mansion in the village of St. Gervais. From this account I have extracted those parts seeming of most interest. In describing the mansion the writer, presumably Houdin himself, says with reference to the avenue gateway, distant about a quarter of a mile from the house: "The visitor presenting himself before the door on the left sees a gilt plate bearing the name of Robert Houdin, below which is a small gilt knocker. He raises this according to his fancy, but, no matter how feeble the blow, a delicately tuned chime of bells sounding through the mansion announces his presence. When the attendant touches a button placed in the hall the chime ceases, the bolt at the entrance is thrown back, the name of Robert Houdin disappears from the door, and in its place appears the word 'entrez' in white enamel. The visitor pushes open the door and enters, it closes with a spring behind him, and he cannot depart without permission.

"This door in opening sounds two distinct chimes, which are repeated in the inverse order in closing. Four distinct sounds then, separated by equal intervals, are

produced. In this way a single visitor is announced. If many come together, as each holds the door open for the next, the intervals between the first two and the last two strokes indicate with great accuracy, especially to a practised ear, the number who have entered, and the preparation for the reception is made accordingly. A resident of the place is readily distinguished; for, knowing in advance what is to occur, he knocks, and at the instant that the bolt slips back he enters. The equidistant strokes follow immediately the pressing of the button. But a new visitor, surprised at the appearance of the word 'entrez,' hesitates a second or two, then presses open the door gradually, and enters slowly. The four strokes now indicated by a short interval succeed the pressing of the button by quite an appreciable time; and the host makes ready to receive a stranger. The travelling beggar, fearful of committing some indiscretion, raises timidly the knocker; he hesitates to enter, and when he does, it is only with great slowness and caution. This the chimes unerringly announce. It seems to persons at the house as if they actually saw the poor mendicant pass the entrance; and in going to meet him they are never mistaken."

Electrical arrangements were also provided for signalling the arrival of a carriage and dealing with the gates in response; while the postman received from a bell at the gate instructions whether to leave the letters in the box, or if it was necessary for him to go up to the house to collect some letters.

"My electric doorkeeper," says Houdin, "leaves me nothing to be desired. His service is most exact; his

fidelity is thoroughly proven; his discretion is unequalled; and as to his salary, I doubt the possibility of obtaining an equal service for a smaller remuneration."

Houdin had a favourite mare, to which he was much attached, and the food for this horse was automatically placed in its trough thrice daily, the apparatus being controlled by a clock in the study. The reason for this arrangement seems to have been that Houdin had found his mare being underfed by a former hostler, who converted as much food as possible into hard cash for his own behoof. In order to prevent the hostler remaining in the stable while the horse was fed, the oats were only allowed to fall into the trough while the stable door was shut and locked, and he could not remain in, as he could only lock the door from the outside. The man could not re-enter while the oats were in the manger without his master being informed of the fact, for if the door was opened before the oats were finished a signal was given in the house.

The power for ringing some bells in the tower was stored in a most ingenious way, for between the kitchen situated on the ground floor and the clockwork in the garret there was a contrivance so arranged that the servants in going to and fro about their work wound up the weights without being conscious of it. The ringing of these bells was electrically controlled by the study clock, which also operated time dials in several rooms.

If Houdin desired dinner earlier he simply pressed a button in the study and put the kitchen clock forward a quarter of an hour. The same clock switched on con-

tinuous ringing alarms to waken the servants in the morning.

Houdin evidently had his greenhouses connected with his study by thermo-electric apparatus, for he would surprise his gardener by saying, "Jean, you had too much heat last night; you will scorch my geraniums," or "Jean, you are in danger of freezing my orange-trees."

The house was fitted with automatic electric fire-alarms and burglar-alarms, the latter being switched on to every door and window at the hour of midnight by the study clock, and again disconnected by the clock in the morning.

It is probably almost half a century since this wonderful mansion was thus equipped. I have found no means of learning exactly when Houdin retired and went to live in it, but it is certain that he was using electro-magnetic apparatus to aid him in stage effects in Paris during the year 1845, at which date we consider electricity to have been in its early infancy.

CHAPTER XXX

HOW WE MEASURE ELECTRICITY

Our present primitive methods of measuring material things—No artificial standards in electricity—A most eccentric genius does much to aid electrical progress—How the electrical units were named —An absent-minded philosopher—An explanation of the units—How the pressure and rate of flow are measured—How the consumption is measured—The earliest consumption meter—How a modern electric meter works—A clumsy method of paying for energy, and an exact electrical method.

TO measure any material thing is an easy matter, for we may compare it with some other known object. One may say that a thing is so many times longer or heavier than a certain other thing, which we agree to take as a standard. Some of the earliest "standards" used were the finger, the hand, the forearm (cubit), the foot, the span, the stride, the mile of one thousand paces, and so on.

Early in the fourteenth century, about ten years after the Battle of Bannockburn, it was agreed that "three grains of barley, dry and round, do make an inch," and "twelve inches make one foot." Even now our methods are entirely artificial, although, fortunately, more definite than these primitive "standards."

It would seem very primitive indeed if our legislators merely made two chalk marks on the floor of the House

of Commons, and then informed us that the distance between these two marks must be reckoned a foot or a yard, or any other name they cared to give it; but in point of fact our present method is really just as primitive, except that we have taken care to preserve the marks for future reference. We have, locked up at the Standards Office in London, a bronze bar thirty-eight inches long, having two gold studs sunk into the bar near its ends, on both studs a line is cut, and the distance between these two parallel marks is the length we have agreed to call the yard, but in order to be as exact as possible the measure must be made when the metal bar is at a temperature of 62° Fahrenheit. All other lineal measures are either smaller parts or multiples of this definite but artificial standard. The unit of weight is the pound, and this is defined by a certain piece of platinum also preserved in the Standards Office. Four copies of these standards are deposited in other places of safety, in case of any accident.

The French have attempted a more natural standard of length, in taking the "metre" as one ten-millionth part of the quadrant of the earth through Paris; but this is not absolutely correct, so the French have their standards preserved in their capital, just as we have.

On visiting the Bank of England one finds that, instead of counting the sovereigns, an official desiring to fill a bag with, say, £1,000, simply weighs out a certain weight of sovereigns as though he were weighing sugar. This is, of course, a perfectly reliable method as the scales are very sensitive, and he already knows by experience that one thousand sovereigns weigh a certain amount, so he is

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A Shock-proof Overall invented by Professor Artemieff for use in Laboratories in which electricity at very high potentials is employed. The electrician is working among these high-tension currents without any fear of shock. The overall is made of fine metal gauze and completely envelops the electrician from head to foot. In the picture it is only visible over the head and hands.

confident that if he gets the weight correct he will have the number of sovereigns also correct. The number of coins is here arrived at by the weight, or in other words by the effect of gravity upon the mass of the coins.

We measure heat by its expansive effect upon a column of mercury or spirit, or by its electrical effect, as explained in an earlier chapter, and in a similar fashion we measure electricity by its effects.

In previous chapters we have noted the magnetic effect produced by a current flowing in a coil of wire, and as the magnetic effect is in proportion to the amount of the controlling current, we have, in this effect, an exact means of measurement, and most electrical measuring instruments are based upon this magnetic effect.

If we take a coil of wire and suspend a magnetic needle in it, we find the magnet deflected more and more as the current increases, but the amount of movement will, of course, be also dependent on the size of the coil, the number of its turns, etc., so where are we to find a convenient standard to lock up? It is fortunate we do not require to base our electrical units upon any artificial standard, as we do for our measures of length and weight.

When electricity came to be used in everyday life it was found necessary to have a definite measure to refer to, for it would not do merely to record, as some early experimenters did, that the current required for a certain result was such that it dashed the needle of his largest galvanometer against its stops, and so on. About forty years ago it became quite evident that a great deal would depend in the practical applications of electricity upon having a proper system of measurements. With this in

view the "British Association for the Advancement of Science" appointed a committee of scientific men, with Sir William Thomson (Lord Kelvin) as its leading light, to suggest suitable standards of electrical measurement. It is not within the scope of this book to show how these absolute units were arrived at, and indeed a statement of the facts would not interest those who have not already gained a certain amount of scientific knowledge, but I think it will be of interest to the general reader to know how electricity is measured by these fixed units.

We have already seen in chapter viii. the great amount of money lost in the early submarine cables, which were not capable of doing the work required of them, and the true explanation of this unnecessary waste seems clearly to lie in the fact that at that time there did not exist any proper electrical measurements.

It is of interest in passing to note that a great deal of credit, in connection with a basis of electrical measurements, is due to the individual labours of a rather eccentric gentleman, the Honourable Henry Cavendish, a nephew of the third Duke of Devonshire. Cavendish was a great genius, and he contributed much of value to many branches of science. Having plenty of this world's wealth he used to shut himself up in his laboratory and busy himself day after day experimenting, from a true love of science. He was in the habit of lending books from his library to any man of science known or recommended to him, and in connection with this it is surprising to find that he was so methodical that he never took down a book for his own use without entering it in

the lending register. I say that one is surprised to learn of this methodical plan, for it is a known fact that this great genius was very careless in recording his scientific results, often merely jotting them down on the backs of old envelopes or other loose scraps of paper, and though a publication of his researches was made, after a lapse of some eighty years, by Clerk-Maxwell, there doubtless must have been many interesting facts never made known. Cavendish was so devoted to his hobby that society had no attractions for him; he only met his heir once a year, he himself being a bachelor, and all his intercourse with the outer world may be summed up in his attendance at the meetings of the Royal Society, and dining with its members once a week. Any instructions to his servants he wrote down and left in a note on his hall table, while his maidservants were ordered to keep out of his sight on pain of dismissal.

The British Association Committee decided to name the electrical units, agreed upon, after the great men of science who had done so much towards the advancement of the science; and it seems to me a pity that the name of Cavendish was not memorialised in some form, although it is sure to be kept in remembrance by all students of physics.

The unit of pressure, or electro-motive force, has been called the "volt," after Volta, who discovered the flow of electricity between two dissimilar metals in contact, which discovery led to the construction of batteries. The unit of current, or rate of flow, was called the "ampere," after the great French scientist of that name

who suggested the galvanometer, and who did much for the science of electricity.

This great physicist was said to have been at all times so absorbed in his work that his wife had very great difficulty in getting him out of his laboratory even when he had some important appointment to keep. The story is told of how on one occasion, when he and Madame Ampère were to attend some great banquet, his wife at last succeeded in getting him away from his experiments, and upstairs to dress, but she evidently did not get him away from the problems working in his mind. After waiting impatiently for his arrival downstairs in evening dress she was at last compelled to go up and ascertain the cause of delay, and one can well imagine her dismay when she found the great genius sound asleep in bed. His mind had been so absorbed that coming away with the intention of preparing to don his dress-suit he automatically went to bed, and having doubtless arrived at a satisfactory solution to the absorbing problem, fell into a pleasant slumber.

The unit of electrical resistance was called the "ohm," after the great German physicist, Professor Ohm, who formulated the law that the strength of an electric current in a wire depends not only upon the electrical pressure driving it through the wire, but also upon the amount of the resistance offered by the wire to the passage of the current. While we are not to think of this resistance as a mechanical friction, yet it is well to fix in our minds that this resistance is an inherent property of the conductor itself, and not in any way

dependent upon the current that happens to be flowing through it.

These three units—the volt for pressure or electro-motive force, the ampere for the rate of flow, and the ohm for resistance—are the three practical units of most common use.

We all have a fair estimate of what a yard or a pound is, and it would be well if we also formed some conception of what these electrical units are like. Some idea of the magnitude of a volt may be obtained from the statement that the electric pressure, or electro-motive force, of a single battery cell is between one and two volts.

In thinking of the ampere we must remember that it is the unit of flow in one second of time, just as one would say of water, so many gallons per minute. It is in amperes we measure the current, while the volts merely indicate the pressure at which the current is supplied. We may think of an ampere as being the current required to make an ordinary glow-lamp bright, but this may vary from one-third of an ampere to three amperes, according to the thickness of the carbon filament which the current has to heat. In an arc-lamp we require a rate of flow of from ten to twenty amperes. Thus the heating of a wire or other conductor depends on the number of amperes passing through it, while the voltage will be determined by the resistance we have to send the current through. The pressure required to work an arc-lamp, with the great resistance offered by the air space between its carbon points, is seldom less than sixty volts, whereas a small glow-lamp, with its continuous

filament, may be worked with as low an electro-motive force as three volts.

It only remains to form some conception of the ohm or unit of electrical resistance. The value of the practical ohm is very conveniently arranged, so that it requires a pressure of one volt to send a current of one ampere through the resistance of one ohm. Here we have a very convenient relationship between the volt, the ampere, and the ohm, for if we know the value of any two of these the third may easily be found. If we have a circuit of two ohms resistance and we have a source of supply at six volts pressure, then we know that the rate of flow will be three amperes, for each volt will cause one ampere to flow through one ohm, so that the six volts would give six amperes through one ohm, but as the resistance is doubled, *i.e.* two ohms, then the six volts will only get the current to flow at half the rate—viz. three amperes. We may count the value of the practical ohm to be the resistance of one-third of a mile of copper wire about one-tenth of an inch in diameter, or one may think of a mile of ordinary iron telegraph wire as having a resistance of thirteen ohms.

It will be clear that we must be able to read both the pressure and the rate of flow; and these are easily indicated by the effect of the current in passing through a coil of wire in which a magnetic needle is pivoted. To measure the pressure we have a voltmeter, which we may consider as analogous to the pressure gauge on a steam boiler; and to measure the rate of flow of current we have an ammeter or ampere meter.

Both of these instruments are galvanometers, having

a coil of wire with a magnet at its centre, or some other arrangement based on this principle. In general appearance they are very similar, and one might quite imagine an Irishman saying that if they were not similar they were the same. In point of fact the only difference is that the ammeter has a coil made of a short thick wire, so as not to obstruct the rate of flow, and the voltmeter has a long coil of thin wire to offer a great resistance to the current.

It seems rather strange that both the pressure and the rate of flow should be independently measured by the effect of the current upon a neighbouring magnet. It is difficult to find an adequate analogy, but one's mind naturally thinks of water, and so perhaps the following picture may be of assistance. If we imagine a pipe through which water is flowing at a constant rate, we might place a very little waterwheel in its course to indicate, by its revolutions, the rate of flow of the water. Again, if we desired to find its pressure, we might apply a definite friction to the waterwheel, so that it would require a certain amount of pressure to turn the wheel at a given rate. This must only serve as a rough analogy, with the waterwheel representing the magnet, but one can see, in the first case, the water left as free as possible to turn the wheel, which corresponds to the ammeter with the heavy wire allowing the current to pass freely. Again, in the second case, we put a resistance in the way of the water, and thus measure its pressure against this obstruction, which in some degree is analogous to the voltmeter in which we place a definite resistance in the form of a long coil of fine wire.

It is unnecessary to describe the details of construction of these instruments, as these particulars may easily be understood from the principle just explained. The dial of the ammeter is, of course, marked off in amperes, and the voltmeter in volts.

It will naturally be very difficult for anyone to realise merely by reading about volts and amperes what these units really are; one only comes to realise what a pound weight or a yard measure is by repeated use of these units.

The meter which will interest the general reader most is the consumption or supply meter. The first current meter was invented by Edison, and many may remember its appearance at the Paris Exhibition of 1881. This meter was based on the chemical action produced by a current passing through a solution of copper sulphate. It was, in fact, an electro-plating apparatus, having two pieces of copper suspended from the opposite ends of a balanced beam. When the current passed from No. 1 copper to No. 2, it plated the latter with copper taken from the solution and replenished by No. 1 copper. As this No. 2 copper increased in weight, with the copper plated on to it, it depressed that end of the balanced beam, which operated a counting mechanism. When this end of the beam came down a certain distance it automatically switched the current on in the reverse direction, so that it passed from No. 2 copper to No. 1 copper, plating the latter this time, which in turn brought the beam down on the other side, see-saw fashion, once more operating the counting mechanism, and again reversing the current. In effect it was simply a means of counting

how often the current was able to carry over a certain amount of copper from the one plate to the other alternately, and as the ability of the current to do this depended on the amount of current passing, a direct reading of the current was registered.

This gave a starting-point for inventors of supply meters, and to-day forms the basis of some modern meters, although in itself it was not a very efficient meter, owing to its having to work at a variety of temperatures, which affected the conductivity of the liquid. It would not be of sufficient general interest to trace the growth of this class of meter, nor even to describe all the different principles at work. I think it will be enough merely to indicate how the measuring is done in the meters in most common use.

Many people are curious to know how an electricity meter works, although they may never bother their heads with the details of a gas or water meter. There is nothing mysterious about these meters to them, for they are operated by substantial matter passing through them; but to talk of measuring electricity seems to them somewhat mystifying. All electric meters, however, are merely means of registering the effect of the current upon certain material arrangements.

The most prominent and most useful property of electricity is undoubtedly its effect upon a magnet. We find this property being made use of in dynamos, motors, telegraphs, telephones, etc., and so it is natural that it should also be used as a measure of the current. The more current one supplies to a little motor the quicker its armature spins round, so that with a delicately-adjusted

armature, arranged to operate a counting mechanism, we have a reliable current meter, with, of course, more detail of construction than is here mentioned, such as a contrivance for reducing the speed and yet keeping the revolutions proportional to the variations in the current passing through the meter.

We ourselves expend a great deal of energy every day in moving about and performing our daily tasks, and we require to lay in a fresh stock of energy, which we do by eating nourishing foods. When we buy food, it is really the energy in the food that is of first importance to us, whether we so consider it or not. Paying for food, however, is a very clumsy method of paying for energy; for we often, wittingly or unwittingly, pay for and consume foodstuffs that add very little energy to our human mechanism; and how often, owing to the hurry-scurry of life, do we fail to extract the available energy from our food. The point I desire to enforce is that while we have here a very roundabout way of paying for energy, we have a very direct and exact method in the electric meter.

It is, of course, the energy of the electric current that we desire to measure, and therefore we must have a suitably arranged unit to work with in practice. We have a dynamo giving out a certain current at a certain pressure, according to the construction of the machine and the speed at which its armature is revolving, so that the energy available will be the quantity of current passing in a given time multiplied by the pressure. The unit for this might be termed a volt-ampere—one volt multiplied by one ampere; but it is more conveniently called a watt, in honour of James Watt, the inventor of practical steam-

engines. This unit is too small to be convenient, so electricians have adopted one thousand watts as a commercial unit of power, and have named this a kilowatt. It is clear that this is only a measure of the power or capability of the current, and the energy the consumer can get from it depends on how long he can get the use of this amount of power; and so the Board of Trade has arranged that the unit is to be a kilowatt for an hour, sometimes called a kilowatt-hour, but better known as a Board of Trade unit, written B.T.U. If the charge is sixpence per B.T.U., it simply means that the consumer is to get the use of a power equivalent to one thousand watts for an hour, and for this he is to pay sixpence. Of course he may spread the using of this kilowatt over any length of time he desires; he may use it at the rate of one hundred watts in one hour, in which case he may continue using that amount of power for ten hours, and then he has taken the B.T.U. his meter will have registered, and at the settling of accounts he has to hand over the required money value to the supplier.

It is well that the consumer should form some definite conception of what he can get from one B.T.U. A sixteen-candle-power lamp is estimated to consume sixty watts, so that he should be able to have that lamp alight for about 16½ hours, at the cost of one B.T.U. It is also well that he should fix in his mind how a B.T.U. is made up, for there often seems to be quite an unnecessary vagueness upon this point. The Board of Trade unit, as already stated, is a power of one thousand watts for one hour, one watt being one volt multiplied by one ampere. He may, if he so prefers, remember the B.T.U. as one

thousand volt-amperes per hour, so that he knows if his current is being supplied at a pressure of one hundred volts then he is consuming ten amperes in his Board of Trade unit. It may be noted in passing that one thousand watts is approximately equal to one and one-third horse power.

Some readers, to whom the subject has been quite new, may still be a little puzzled as to the meaning of the *ampere.* The other units seem to be more easily grasped than this one, but I think the difficulty arises from an omission to remember that the ampere is not really a measure of quantity, but is a rate of flow, or current strength. The measure of electric quantity is really the coulomb, called after a great French physicist, who lived during the French Revolution. A coulomb is the quantity of electricity required to produce a definite chemical effect, to deposit 1·1183 milligrammes of silver. An ampere is the rate of flow of a steady current of one coulomb per second, just as one may speak of a flow of water being at the rate of one gallon per minute. If we had one single word to represent the phrase "one gallon per minute," then we should have a corresponding word referring to the rate of flow of water, just as we have the single word "ampere" to represent the rate of flow of electric current.

To be told that water is flowing through a pipe at the rate of so many gallons per minute does not indicate the quantity of water that has passed until one knows for how many minutes or hours the water has been flowing. In a similar manner if we are given the rate of flow of a current in amperes, we must also know the duration

of the flow before we can tell what quantity has passed. A two-ampere current will have conveyed in one hour 7,200 coulombs, which figure is simply calculated as 2 amperes × 60 seconds × 60 minutes. If we have a current strength of only one-tenth ampere, then it will take ten seconds of flow before one coulomb has passed.

Speaking of a waterwheel, we may say that we require a flow of so many gallons per minute to drive it, and in the same way we may say that we require a current of so many amperes to keep the filament of an electric light glowing. The general reader is constantly coming across the word ampere, but he seldom meets the word coulomb, as it is included in the word ampere, the meaning of which, as already pointed out, is a rate of flow of one coulomb per second.

It is obvious that if there is a fixed pressure or voltage one can vary the rate of flow, that is, the amperes, by altering the amount of resistance in the path of the current, just as one does in drawing water off the main through an ordinary stop-cock. The further one draws the stop-cock out of the pipe the greater the rate of flow, and the greater resistance one leaves in the path of the water the smaller is the rate of flow. As already explained, the electrician places coils of various thicknesses of wire in the path of the electric current, and in this way he is able to regulate the current strength. If we wish to maintain the same rate of flow (amperes) through an increased resistance (ohms), then we must increase the pressure (volts). We already saw that it requires one volt of pressure to drive a current of one ampere strength through a resistance of one ohm, it will therefore require

a pressure of two volts to send the same current through a resistance of two ohms. If we had left the pressure at one volt and still increased the resistance to two ohms, then, of course, the rate of flow would have been only half its original, or half an ampere.

While the ampere indicates the rate of flow, it is plain that if a current of one ampere be allowed to flow for one hour, then we have a definite quantity of electricity, which we term an ampere-hour. It requires a certain pressure to send this current through the circuit, dependent upon the resistance offered. If an ampere-hour be multiplied by the pressure (volts), then we have the consumption of electrical energy in watt-hours, one thousand of which are called a Board of Trade unit.

CHAPTER XXXI

SOME QUESTIONS ANSWERED

The meaning of positive and negative electricity—How to tell in which direction a current is flowing—An amusing conversation—The current that kills—The resistance of the human body.

THERE are a great many points of importance which I have deemed it inadvisable to touch upon in the foregoing chapters because, to many readers, these would doubtless seem dry and uninteresting. It is, however, probable that in the minds of some readers there will be a desire for further explanation, and so I have thought it well to devote this chapter to answering such questions as might naturally arise. These few preliminary words will serve to mark this chapter as intended only for the latter.

I think the first question would probably be regarding positive and negative electricities, the mention of which has been so scrupulously avoided in the whole of the preceding chapters. These are merely arbitrary terms, but they serve a very useful purpose, and part of the foregoing explanations might possibly have been made simpler by the use of these terms, but my experience has been that, to many people, these and kindred terms are rather

a worry: hence my avoidance of them. These terms of positive and negative originated with the one-fluid theory of electricity, in which the + sign was used to indicate an excess of the supposed fluid and the − sign a deficiency, the earth being taken as zero, or we might say as the electrical sea-level. These terms have really no connection now with the idea of more and less. We have direct evidence that there are two distinct kinds of electricity.

The general reader will be interested in these terms in their connection with electric currents rather than as regards electrified bodies, so I will merely deal with them in the former connection. We form a mental picture of the electric current flowing from the positive pole of a battery or dynamo round the circuit, through the lamps, etc., and back to the negative pole. In a simple battery cell we speak of the current passing from the carbon connection through the connecting wire to the zinc element, and so we call the carbon the positive pole and the zinc the negative pole. In a dynamo the position of the poles is according to the direction of winding the coils.

It is easy to discover in which direction a current is flowing in a wire by its magnetic influence on a neighbouring compass needle. If the wire carrying the current be placed over the compass needle, which is pointing north and south, and when the current passes, the needle turns its north pole to the east, then we know the current is flowing in the direction from north to south. Of course the magnetic needle need not be placed in its natural position as in a compass. It may be mounted on its centre in an upright position at the back of a dial, as in

a galvanometer, and the indicator on the face, moving with the magnet, will show its movements, falling to one side or the other according to the direction in which the current is sent through the coil surrounding the magnet.

It was recognised by some of the earliest workers that there were two distinct kinds of electricity. Later workers departed from this idea. Indeed it is not so long since some of the foremost scientists of our day thought for a time that electricity was not a real thing, but that electric currents and electric charges were merely phenomena in the ether of space. We have direct evidence now that electricity is a real existing thing.

I was very much amused in overhearing some remarks which passed between two gentlemen in a public conveyance. One asked the other how it was that a person might walk along the rails of an electric tramway and yet not receive a shock from the dynamo to which they are connected. His friend's reply was that the rails only carried negative electricity, which was quite harmless, and that it was the positive electricity, carried by the trolley wire, that killed. This gentleman would doubtless have been surprised if he had been told that a tight-rope dancer could walk along the trolley wire with as little fear of electrocution as upon the rails. The space between the overhead wire and the rails is just like a break in the circuit through which the current flows from one brush of the dynamo to the other. When the car comes along it closes the circuit, allowing the current to flow down the trolley pole, through the motor, and away back to the dynamo by the rails. If a person gets in contact with the rails and the overhead wire, owing to

the falling of the latter, then the person becomes part of the electric circuit, and receives a fatal shock. If the person is not on the rails, but on the ground, when the overhead wire touches him, he will undoubtedly receive a shock, but the resistance to the current will be so much greater that no very serious injury is likely to be done.

The tramway motor-men are supplied with rubber gloves with which they may handle a live wire in the event of its coming down. Their duty is to place the end of the wire on one of the rails, whereupon the current is given such an easy path, allowing so great a rush of current, that the safety devices at the power-station come into action and automatically cut off the current.

It may have occurred to some to wonder what amount of current really does kill. Even nowadays one very occasionally comes across some elderly lady or gentleman who fears that death may result from an ordinary battery current. I have fallen in with two such cases quite recently, but with the widespread use of electricity such mistaken ideas cannot survive long even in distant rural districts. Many of us, when youngsters, were informed that birds were often electrocuted by resting on the ordinary telegraph wires. While it is true that a great number of birds are found lying dead immediately below telegraph lines, it is generally known now that their death has been brought about by sudden collision with the wire, against which they have accidentally flown. Hence the little pieces of wood one often sees fastened to telegraph wires in the country are there to attract the attention of the birds to the presence of the wire. From

what has already been said regarding the trolley wires, it will be clear that even if a bird were to rest on a "live" wire, as one sometimes does see on a country road along which a tramway runs, the bird receives no shock, the bird not forming part of an electric circuit.

Even now one often finds some people afraid lest they may receive a fatal shock if handling the connections of an ordinary glow-lamp. Of course this is impossible, and yet one knows that fatal shocks may be received from the conductors for arc-lighting. Where, then, is one to draw a distinctive line? The current supplied for domestic lighting is at a low pressure, which cannot possibly do any serious hurt; but it is not entirely a case of pressure, for a person may receive without injury a high-frequency current from an induction coil, etc., with a pressure of many thousands of volts. In the case of high-frequency currents the amount of electricity is very small. At a pressure of 100,000 volts the current may only be about one-thousandth part of an ampere, although I have seen a medical friend receive as much as one two-hundredth part of an ampère, or five milliamperes.

The current that will pass through any body depends upon the resistance it offers, as well as the pressure of the current applied. Fortunately the resistance of the human body is very high, being estimated at about ten thousand ohms, but if a person grasp two metal conductors the resistance from one hand to the other through the body may only be from one to three thousand ohms. If some vital part of the body offer one thousand ohms resistance to a current at five hundred volts, then half an ampere current will pass through it, and this may be

termed a current that kills. I know of a recent case where a workman accidentally touched two terminals of a machine receiving current at five hundred volts and he was immediately killed, but in this case there was very little resistance offered to the passage of the current, as the man's head touched both terminals. The current for domestic purposes is supplied at a pressure of about two hundred and fifty volts, so the human body is a safe resistance against this current. There is no doubt that some of the fatalities from electric shock are really due to the accompanying nervous shock.

There were some interesting experiments made recently relative to the conductivity of the human body, and it was found by means of very delicate indicating apparatus that the electrical resistance of the same person was continually varying. It would oscillate, even if a third person entered the room during the experiment, and quite a marked difference was obtained by a change of diet. I quote two results which were given in a continental journal, as these seem of interest to the general reader: "Any sensation or psychical emotion of some strength will reduce instantaneously the resistance of the human body down to a value three to five times less." "Nervous persons, as well as heavy smokers and drinkers, are found to have an exceedingly low electric resistance." The first of these two quotations seems to me to have a definite bearing upon fatal shocks. There is often an alarming display of flashes when a conductor breaks, and in this way the normal resistance of the human body may be very greatly reduced, owing to unusual alarm and nervousness. It is well to know that apparent death

from electric shock is sometimes only suspended animation, as is the case in drowning, so that artificial respiration should be tried.

One used to hear people laying stress upon the great risk accompanying the use of overhead electric wires in connection with tramway systems. That there is no real cause for alarm, provided proper care is taken, is evident from the experience of Glasgow. This great centre of industrial activity adopted the overhead wire system in 1900, and by 1910 there was in use about one hundred and ninety miles of overhead wire. During all these years there was not a single fatality caused by the breakdown of an overhead wire.

CHAPTER XXXII

WHAT WE KNOW ABOUT ELECTRICITY

What is electricity?—Some questions we may answer, since the discovery of "electrons"—What is matter?—What is an electric charge?—What is an electric current?—The difference between a continuous and an alternating current—What is magnetism?—The ether of space—What is light?—Discovery of a missing link—What is heat?—What is chemical union?—Importance of the electron theory.

MANY years ago I heard one workman explain to another that electricity was made of sulphuric acid and lead. He was evidently aware that accumulators contain lead plates and dilute sulphuric acid, and he knew that electricity was drawn from these accumulators at will, therefore it seemed to him as though electricity must be composed of these substances.

People sometimes twit the electrician with the question "What is electricity?" as if his branch of science was very deficient in real knowledge compared with other departments of science. If the questioner is asked "What is matter?" he will no doubt realise that none of these very simple-looking questions are so easily answered. It will be of interest, however, to see how far we have succeeded in explaining the mysteries of electrical phenomena.

Suppose you were asked "What is water?" you might reply that it is built up of very small particles or *molecules* of water, each of which is composed of two atoms of the gas hydrogen and one of oxygen. In the same manner, we believe we may answer the questions What is matter?—What is an electric charge?—What is an electric current?—What is magnetism?—What is light? —What is heat? and so on. Some of these questions may seem to have no direct connection with the subject of electricity, but we shall see that a very intimate relationship does exist in each case.

When electricity at high tension from an induction coil was passed through a vacuum tube, such as has been described in connection with X-ray work, it was found that a stream of flying particles was shot across the tube from one electrode to the other. At first it was supposed that these flying particles must be atoms of matter, but later it was proved that these particles were not matter. They are far smaller than the invisible atoms of matter. Scientists were forced to the conclusion that these were particles of electricity and they were christened "electrons," after the Greek word for amber.

A great deal of attention was directed towards these *electrons*, which some have preferred to call *corpuscles.* It was found that those particles of electricity were always of the kind called *negative.* It will be remembered that from the early days it was evident that there were two distinct kinds of electricity, although it was a single-fluid theory that suggested the names *positive* and *negative.* We have definite proof that negative electricity is made up of small particles, just as matter is

molecular in nature. We have no definite evidence as to the nature of positive electricity, but the discovery of the negative particles has opened up a whole world of new interests to us.

We believe the atoms of matter to be composed of little congregations of these electrons. We picture each atom as a miniature solar system; a group of electrons revolving at enormous speeds. Of course, electrons being little particles of *negative* electricity would all tend to fly away from one another, just as any two similarly electrified bodies will. We therefore picture a counterpart of *positive* electricity in each atom, but what form it takes we cannot determine. Until recently it was common to picture the electrons revolving within a tiny sphere of positive electricity. Now it seems likely we shall find positive electricity to be molecular in nature also. In other words, that it will turn out to be composed of particles, which although much larger than the negative electrons, are still infinitesimally small.

We have always recognised the fact that an atom of gold must be something quite different from an atom of lead or of hydrogen gas. We now believe the real difference to be due to the number of electrons which compose it. We must understand that these revolving electrons are locked up within the atom. We cannot interfere with their energy. We may heat the substance, composed of the atoms, to a temperature of thousands of degrees, or we may chill it down till its temperature reads three hundred degrees below zero on the Fahrenheit scale, and yet the atoms remain as before. The substance will, of course, alter from a solid to a liquid or a gaseous condi-

tion, or the other way about when cooling. But an atom of gold remains always an atom of gold, and an atom of hydrogen cannot be changed into anything else. Atoms have been called the little bricks of nature. The electron theory has added to this picture, for now we have some idea of what these invisible bricks are composed.

In very rare cases we see evidences of an atom breaking up, and some of the electrons escaping from within the atom. The most notable case is that of radium, of which we read in an earlier chapter. But I have mentioned electrons flying across an X-ray tube. Where did these come from? It is quite evident that they cannot come from the inside of the atom; they must have been outsiders. We have ample evidence that there are a great many electrons which are attached only in a temporary manner to the atoms of matter. Indeed, we picture these as roving electrons wandering about from atom to atom.

The old-world experiment of rubbing a piece of amber with a fur or cloth has a new interest to us. We have caused a surplus of these roving or detachable electrons to leave the rubber and take up their lodgment upon the amber. We have added so many little particles of negative electricity to the amber that it shows an appreciable negative charge.

A body charged with electricity has therefore a new meaning. If it is *negatively* charged, we picture a surplus of electrons upon its surface. There must of necessity be a corresponding deficiency of electrons on some neighbouring body or bodies, and we describe this condition as *positively* charged. The transfer of electrons from one

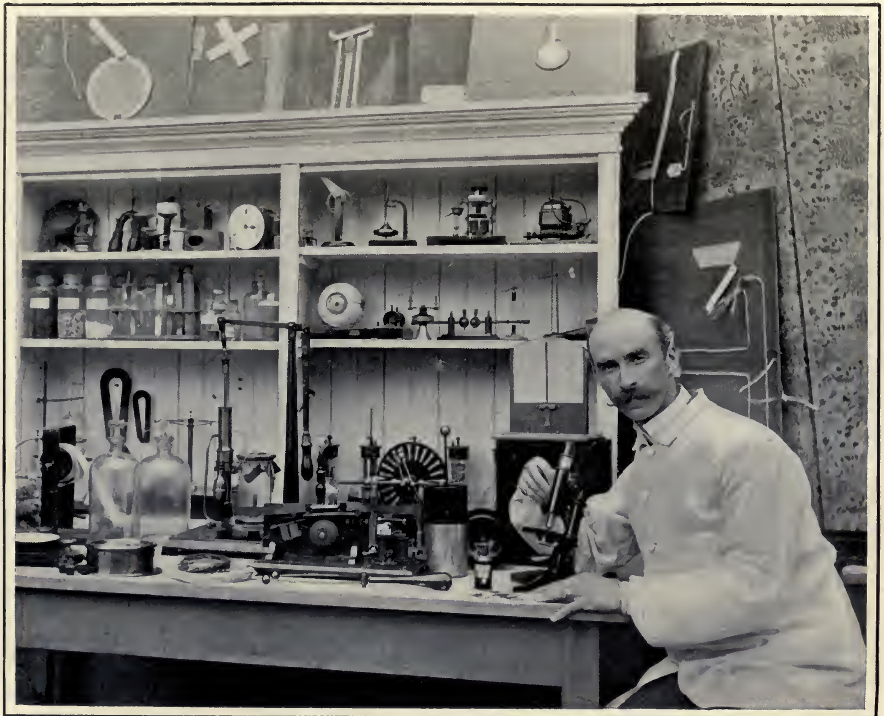
body to another affects the surface only. Long before we knew anything about electrons, we were aware that an electric charge resided only upon the surface.

When we speak of a discharge of electricity, such as we see on a grand scale in lightning, we picture a sudden expulsion of electrons from one body to another. In the case of lightning it is from one cloud to another, or between a cloud and the earth.

When Volta made the first electric battery, he caused the atoms in the zinc plate to hand electrons along the connecting wire to the atoms in the copper plate. The electrons were handed on from atom to atom in the wire, each atom giving up a spare electron to its neighbour on one side as it accepted an electron from its neighbour on the other side.

We therefore picture a steady flow of electrons along a wire, and we say that an electric current is flowing in the wire. These moving electrons disturb the ether of space surrounding them, and the energy of the electric current is carried really by the ether. It is well to take particular note of this, lest any one should imagine that the electrons fly along the wire with the speed of the electric current. As a matter of fact, the rate of travel of the electrons may be measured conveniently in inches per minute, or in yards per hour. The action, however, commences simultaneously along the whole line.

When considering dynamos, we saw that we might produce either a *continuous* or an *alternating* current in the mains. In the former case we set up a regular march of electrons from atom to atom along the line. But in the case of an alternating current, we cause the electrons to surge to-and-



A Corner of the Author's Laboratory.

fro from atom to atom, say first of all in one direction and then in the other. Of course the surrounding ether will be disturbed, and energy will be transmitted just as in the previous case.

In addition to these roving electrons, we picture others which revolve steadily around certain kinds of atoms, particularly the atoms of iron. These moving electrons produce magnetism. This helps us to extend the picture of a magnetic body which we considered in chapter IV. But if moving electrons produce magnetic effects in the surrounding ether, we should expect the steady flow of electrons along a wire to produce magnetism also. We have known this to be a fact for nearly a century, although no reason could be assigned for it. It was a Danish philosopher who, in 1819, discovered that an electric current flowing in a wire set up a magnetic field around it.

Possibly the repeated mention of this *ether* of space is rather mystifying to some readers. The nature of the ether is a very great mystery to every scientist. This does not mean, as some might suppose, that the ether is not a real existing thing. To all who consider the subject seriously it is as real as the air they breathe.

It would be better if we agreed to spell the name of this mysterious medium *æther* instead of the much more common spelling *ether*. The word *æther* seems to take us farther away from any known form of matter, and it is quite evident that, whatever may be the nature of the space-filling medium, it is not any form of ordinary matter. One theory suggests that it is an infinitely light gas, while another demands for it a density greater than

that of lead. The latter theory may appear, at first sight, to be quite ridiculous. But if we picture matter as holes in a very dense medium, the theory is not inconceivable. However, all that concerns us at present is that although the nature of the ether is a complete mystery, its presence is very real, and the part it plays in the Universe is of primary importance.

We know that light is simply waves in this all-pervading medium. We are familiar with the fact that a substance when heated to an incandescent state will set up these ether waves of light. Until quite recently it was a mystery to us how atoms of matter could disturb the ether, for it is apparent that even huge lumps of matter such as the planets can move through the ether without any appreciable resistance being offered to their movements.

Here we are on the back of a great planet flying through space at the enormous speed of one thousand miles per minute, and the ether does not disturb even our flimsy atmospheric blanket, which we carry wrapped around us in our great flight.

The electron theory supplies the missing link between the ether and matter. We have experimental proof that there are satellite electrons revolving around their atoms just as the Moon revolves around our Earth. These satellite electrons make billions of revolutions per second, and in doing so they disturb the ether and produce those waves which we call *light*.

If these satellite electrons revolve at a comparatively slow rate they produce long ether waves; in other words, waves few and far between. These waves do not affect

our vision, but they produce heat. We call them *radiant heat* waves, but, of course, they are not warm; they are merely waves in the ether. The Sun sets up such waves and they reach us across the space of millions of miles, but that space is not heated. It is only when these ether waves fall upon matter that they produce the phenomenon known as heat. A flying bullet on the battlefield may produce pain when it strikes a soldier, but the flying bullet is not the pain.

When the satellite electrons revolve at a speed sufficient to produce the short waves which affect our eyes, these waves give rise to a variety of sensations. A certain rate of waves produces the sensation of red, a higher rate gives rise to green, while a still higher rate stimulates the violet sensation. When all these waves fall upon the same part of the retina at the one time, we have that sensation which we describe as *white*.

Another point upon which the electron theory has shed new light is the nature of chemical union. We have no doubt that chemical union is simply electrical union between the atoms of matter. It is really a case of electrical attraction between oppositely charged atoms. This adds a new interest to electro-chemical actions. We see how it is that by passing an electric current through water, we get the atoms of hydrogen and oxygen to part company and escape as oxygen and hydrogen gases.

We have answered, in some measure, the questions with which we set out, regarding the nature of matter, electric charges, electric currents, magnetism, light, and heat. It has only been possible to draw the very barest outline of the electron theory. The subject is so large that to give

even a popular account of it requires a volume as large as the present one. I have endeavoured to do this recently in a book entitled *Scientific Ideas of To-day*.* That the electron theory appeals to the general reader, as well as to the scientist, is witnessed by the fact that this popular account to which I have referred has gone into a third edition within its first year. Personally I believe that the electron theory is the beginning of a new era of thought.

* *Scientific Ideas of To-day.* By Charles R. Gibson. Seeley and Co. Ltd., London. Five Shillings net.

CHAPTER XXXIII

CONCLUSION

More wonderful than Aladdin's lamp—A brief historical review—Slow progress prior to the nineteenth century—An international advance—Davy and Faraday—A genealogical table—Present achievements—Future possibilities.

WE have seen how electricity serves mankind, enabling us to hold immediate communication with all parts of the world; or carrying for us the mighty power of the waterfall to distant towns by means of a stationary wire; or making it possible for us to actually hold conversation with friends distant hundreds of miles. Does not the simple statement of these and similar facts read as a fairy tale, and are they not, in truth, far more wonderful than all that Aladdin's lamp did for him?

It is remarkable that all the practical applications of electricity have been made during the last century, and that the most of these have been begun during the lifetime of many people now living. Within the last decade we have seen many new fields opened up in the electrical world, the most conspicuous applications being X-ray work and wireless signalling. The experimental work with radio-active bodies has also a close connection with electricity.

BRIEF HISTORICAL REVIEW

Electricity had been known from early times, there being records relating to rubbed amber as far back as 640 B.C., and the discovery of magnetism in the lodestone or natural magnet is a matter of ancient history, having been recorded at a much earlier date than the observed phenomena of electrical attraction in rubbed amber. It does seem strange that these phenomena, which have now led to such marvellous results, were allowed to lie practically dormant for a space of twenty centuries. During that long time generations of men came and went attaching little, if any, importance to these great discoveries, excepting to use the lodestone as a guide in desert marches. It was not until the dawn of the seventeenth century that any serious attention was given to this important subject. About the year 1600 Dr. William Gilbert, one of Queen Elizabeth's private physicians, wrote a book describing many experiments he had made, and deducing from these that the earth itself was a huge magnet, and that it was possible to magnetise a piece of iron by the earth's influence. Gilbert also suggested that terrestrial magnetism and electricity were both allied emanations of a single force. One very important discovery of Gilbert's was that amber, which had so long been known to possess peculiar properties when rubbed, had no monopoly of these properties, but that they were also exhibited by a very great number of bodies when rubbed. By direct experiment Gilbert was able to show such bodies as glass, sulphur, sealing-wax, hard wood, etc., attracting light bodies towards them after friction had been applied to their surfaces.

But although Gilbert wrote down very clearly in Latin

all that he had discovered and proved, the subject received very little attention for another century and a half. During that time people had certainly taken some little interest, for they had constructed simple machines to do the "rubbing" for them on a larger scale, and with the increased effects a few additional phenomena had been observed, but the advance of knowledge in this branch of science was extremely slow. It was Germany that gave the lead in the making of these early electrical machines.

About the middle of the eighteenth century Benjamin Franklin, the great American philosopher, discovered the identity of electricity with lightning, and before the century had closed Professor Galvani, of Italy, made known his observations on the twitching of a dead frog's legs due to an electric discharge. His fellow countryman, Volta, a celebrated physician of Bologna, in following up the observations of Galvani, discovered a means of producing a continuous electric current. Progress now became more rapid, for with the dawn of the nineteenth century a very close relationship was proved to exist between electricity and magnetism. We are indebted to the native land of Her Majesty Queen Alexandra for this very important discovery, for it was Hans Christian Oersted, of Denmark, who observed the effect of an electric current upon a neighbouring magnetic needle. About this time Professor Ampère, of France, and Dr. G. S. Ohm, of Germany, whose names are embodied in present-day electrical units, did much to make the meaning of things clearer. It was also about this same time, or, to be more exact, in 1822, that Professor Seebeck, of

Berlin, discovered that electricity could be produced by heat.

While it was an Englishman who in 1600 laid the foundations of electrical science, it is clear that, after a long lapse of years, the progress was very materially aided by America, Germany, Italy, France, and Denmark; but when we come to a study of modern developments we find two Englishmen taking a very strong lead. Indeed, we may look upon Sir Humphry Davy and his co-worker, Michael Faraday, as the pioneers of all the great industrial applications of electricity. These two great men worked together at the Royal Institution, in London, Faraday acting as assistant to Davy. It is interesting to note in this connection that although Davy was only Faraday's senior by a dozen years, he did not live to see any of the great electrical industries begun, while Faraday, who along with Davy laid the foundation-stones, lived to see many electrical applications launched on a business footing, as he did not die till the year 1867.

There is an interesting story told of Faraday, which serves to show his very practical turn of mind. An American inventor came over to this country in the early days of electrical enterprise, exhibiting a large electrical motor machine, with the object of floating the same for industrial purposes. A number of eminent men of the day were asked to give their opinions regarding this new kind of motor. Some gave great praise, but Faraday stood for some time watching the machine at work, and then, without making any remark, he went to the corner of the room, and picking up a broom, he applied the handle of it as a brake upon the large fly-wheel

till he almost brought the motor to a standstill; then, letting it go free, he left without making any public statement. It must have been clear to the inventor that his motor was not capable of driving any load. Of course this genius had no better source of power than a large and clumsy chemical battery.

This review has purposely been very brief, and is therefore necessarily incomplete, including merely those items of most general interest. A very simple genealogical table might be formed, beginning with lodestone and rubbed amber, the latter leading to the construction of frictional machines; then the discovery of the action of one of these machines upon the legs of a frog. It being found that the contact of two dissimilar pieces of metal produced the same twitching effect as the electrical machine, a battery of metal discs was made, and these placed in acids gave us the principle of all batteries. The observed effect of this battery current upon a neighbouring magnetic needle gave the basis of all telegraph and telephone apparatus, and when it was discovered that the converse was true and that a magnet could so influence a moving conductor as to set up an electric current in it, then dynamos, motors, induction coils, etc., soon followed.

Lord Kelvin (Sir William Thomson) one of the foremost workers in the electrical world, has passed away since the date of the first edition of this volume. His ingenuity made submarine telegraphy possible; he added a great deal to our electrical knowledge. Professor Sir J. J. Thomson, of Cambridge, and Sir Oliver Lodge, of Birmingham, are conspicuous in connection with modern ideas of electricity.

To sum up in detail the benefits we have already obtained from electricity would require considerable space, and is quite unnecessary; it will be sufficient to remark upon a few of the principal applications. As a speedy carrier of news, electricity has no rival. It also holds a unique position in transmitting speech over great distances, and quite recently we have the almost inconceivable achievement of speaking through space without any connecting wires. While as an illuminant electricity has rivals which successfully compete with it, it possesses many advantages over its competitors, the one obstacle to its general use being its greater cost. As a means of conveying power from one place to another, electricity stands head and shoulders above all other methods, making it possible to take advantage of the energy of large waterfalls. We have seen how electricity now aids the physician and the chemist, whilst a host of other interesting applications have been dealt with.

It would be idle to prophesy regarding the future possibilities in the electrical world, but there seems little doubt that in time we shall have a complete electrification of our railways. Our present method of making the source of power drive not only itself along, but also a heavy supply of coals and water for its own consumption, does seem a very clumsy proceeding when compared with a fixed generating plant dispensing power in wholesale fashion to all the trains upon a particular route. It is very remarkable that the trains have merely to be in contact with a stationary wire, which conducts current from the dynamos to the electric motors on board the train. We must look upon these motors as merely con-

verters, transforming electrical energy into mechanical motion. There will, no doubt, be a great increase in speed on electrified railways, and it is quite possible that the ordinary speeds of the next generation would at present appear quite ridiculous to us if they could be correctly predicted. Our grandfathers said that people would as soon be shot off like a Congreve rocket as trust themselves to the mercy of a steam locomotive, the speed then being about eighteen miles per hour. Nowadays we ride at a speed of fifty miles an hour, with an occasional short run of ninety miles per hour.

It seems to me very probable that before another generation has come and gone people will have no cause to grumble at smoke and dirt in the atmosphere of cities, as the whole energy required for motive power, heating, and lighting may be delivered from one great generating station outside of the city. When the cost of electricity has been greatly reduced its use will doubtless become quite universal, and in future days the housewives will not have to trouble about the making of fires for heating and cooking. It may be that both the heating and lighting will be regulated by automatic devices, which even now would be possible though extravagant.

When using the telephone of the future, we need not be surprised if, when calling up a friend without the aid of exchange operators, we hear our friend's voice reply that he has gone out and does not expect to be back till late in the evening, but begs us, if it is any message that can be left for him, just to speak it into this automatic machine which is at present speaking, and it will deliver the message to its master on his return home.

Doubtless there will be advances during the next century that the mind of man has not yet conceived, for the patient research of so many able workers is bound to be productive in leading to further practical applications. When Franklin was asked what use there was in some of his experiments, he would reply in Scotch fashion by asking another question, "What is the use of a baby?" and when the illustrious Faraday was similarly questioned he would say "endeavour to make it useful."

It was only yesterday we knew nothing of X-rays, wireless telegraphy, etc., and doubtless there are other and greater surprises awaiting even the present generation of men, while those things which we now class under "modern electricity" may ere long be catalogued as "early ideas and undertakings in ether."

INDEX

INDEX

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